# 農林學報

## 第九、十輯



## 目錄



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# 編者的話

一、本學報第九輯原應於四十九年十二月問世，第其間因集稿等費時，未克如期出版。後省立農學院於五十年七月間奉令合併設立中興大學，於是本學報乃由前省立農學院編輯委員會與省立中興大學農學院編輯委員會共同策劃付梓，遂改爲第九輯與第十輯合刊，於五十年十二月出版。

二、本輯論文編列次序，仍按照前省立農學院編輯之先例，卽依照作者所屬學系成立先後次序；如農藝、森林、農化、植病、農經、園藝……等依次排列。

三、本輯之印刷費用承國家長期發展科學委員會補助，謹此誌謝。至本輯編印匆促，錯誤在所難免，尚祈讀者諸君不吝指正，爲幸。

# 臺灣之三角藺

林本教

# THE TRIANGLE RUSH IN TAIWAN

by

B. J. Lin

## 一、緒言

本省一般稱三角藺爲蓆草或鹹草。三角藺爲本省重要之編織料作物。其主要用途爲編織草蓆及「疊表」。其他可編織草提包、草鞋、草袋等，又可供爲結束物、造紙原料等等，其用途甚廣。最近更用以編製地蓆及草繩。地蓆爲地毯之代用品，近年來外銷數量增多，爭取不少外匯。最近有裝設新式電動編織機，代替舊式人力編織機編織疊表，其工作效率及產品之品質改進甚多。將來疊表亦有外銷之希望。三角藺之加工，已漸成爲本省重要加工業之一。就生產而言，近年來栽培面積及產量之增加甚迅速，單位面積產量亦有增加。本省之氣候土壤適於栽培三角藺，如在栽培技術上再加以改進，則可以增加單位面積產量，提高品質，在不影響糧食生產原則下能振興三角藺生產。本文敍述本省三角藺之沿革、生產、性狀、氣候土宜、栽培及收支情形，並提出今後改進栽培之要點，以供爲發展三角藺生產之參考。

本文之資料，一部分採自各參考文獻外，其他由筆者數次往本省主要產地高雄縣岡山鎮五甲尾，臺南縣仁德鄉太子廟兩地調查而得者。調查期間爲 1959 年 10 月至 11 月。

本文承蒙恩師林碧滄、羅時晟兩教授提供寶貴意見，黃克家先生協助調查，才得以完成，在此深致謝忱。

## 二、沿革

三角藺之學名爲 Cyperus tegetiformis, Roxb.，英名爲 tri-angle rush，屬於莎草科（Cyperaceae）。其別名甚多，所謂七島藺、芷茲、琉球藺、豊後藺等均爲異名同種物。

三角藺原產於東亞熱帶地區，我國南部、琉球、南洋等地均有野生者。我國之廣東、臺灣兩省栽培頗盛，日本之九州亦有大量生產。三角藺在我國之栽培史甚久。臺灣之三角藺可能由我國大陸傳入。據調查，岡山約於200年前開始栽培，仁德於清朝，彰化縣大村鄉約於 60 年前，北投約於 50 年前。

## 三、生產

三角藺分布於全省各地，多栽培於易患水災之低窪地，其他一般水田、河旁、海濱亦有栽培。本省光復後歷年來三角藺之栽培面積及產量如表 1。1959 年本省主產各縣之栽培面積及產量如表 2。

表 1　臺灣三角蘭歷年栽培面積及產量

| 年　度 | 栽培面積（公頃） | 產量（公噸） | 一公頃平均產量（公斤） |
|---|---|---|---|
| 1946 | 204 | 936 | 4,594 |
| 1947 | 316 | 1,521 | 4,822 |
| 1948 | 224 | 858 | 3,831 |
| 1949 | 262 | 1,1[illegible]8 | 4,264 |
| 1950 | 232 | 1,596 | 6,887 |
| 1951 | 334 | 2,675 | 8,006 |
| 1952 | 330 | 2,669 | 8,073 |
| 1953 | 288 | 2,317 | 8,053 |
| 1954 | 426 | 3,067 | 7,207 |
| 1955 | 483 | 3,582 | 7,420 |
| 1956 | 553 | 4,561 | 8,241 |
| 1957 | 589 | 6,884 | 11,688 |
| 1958 | 707 | 8,024 | 11,356 |
| 1959 | 672 | 8,853 | 13,176 |

註：本表根據臺灣農業年報之資料編製。

表 2　1959 年臺灣三角蘭主產各縣之栽培面積及產量

| 縣　別 | 栽培面積（公頃） | 產量（公噸） | 一公頃平均產量（公斤） |
|---|---|---|---|
| 臺　南 | 236.59 | 3,482 | 14,717 |
| 高　雄 | 226.40 | 3,073 | 13,575 |
| 彰　化 | 104.50 | 1,485 | 14,214 |

註：本表根據臺灣農業年報（1960）之資料編製。

臺南縣之栽培集中於仁德鄉，高雄縣於岡山鎮，彰化縣於伸港鄉。三角蘭栽培面積之消長，直接受生產物之價格及穀價之影響。

## 四、性　　狀

### 1. 地　下　部

地下部分爲根及根株 (rootstock) 二部分。根株爲地下莖 (underground stem) 之一種，橫生於地下，圓筒形，直徑 0.5～0.6 公分，呈黃褐色，外被黑鱗葉，其上甚多節，節間短，由節生根及芽。芽伸出地面後，長成爲地上莖。

### 2. 地　上　莖

莖高 1.5～2.0 公尺，直徑 0.6～0.7 公分，橫斷面呈三角形，頂部有數枚大小不同之苞片。地上莖之構造分爲表皮、葉綠組織、維管束及保護組織、網狀柔組織四部份。皮部强靱，表面光滑而有多數線條。內心部呈白色，其無色之圓大細胞呈網狀發達，而存有多數之空腔，維管束則散在內心部。

### 3. 葉

生於莖之基部，下部之 2～3 葉無葉身，上部之 2～3 葉有葉身。葉身長 12 公分，寬 0.7 公分。無葉耳及葉舌。葉鞘長，緊包莖部。

### 4. 花　　序

於晚夏，花序開始散開着生於莖頂，由 8 枝左右之穗梗所組成。穗梗之長短不同，長者達 6 公分，其先端有數本至十數本之分枝，各分枝之頂端着生小穗。小穗之長短亦不同，長者 2 公分，愈先端者愈短小。每一小穗生 14～25 花，每花有雌蕊 1，雄蕊 3，頴 1。開花順序爲由下方之花逐漸往上方，於上午開花。

### 5. 頴　　果

細小，呈紡錘形，濃褐色，橫斷面三角形，長 0.19 公分，寬 0.04 公分，厚 0.03 公分，其一端附着三枝絲狀體。

### 6. 種　　子

極細微，呈楔形，長 0.11 公分，寬 0.03 公分，厚 0.023 公分。種子可發芽生長，如小心育苗，亦可由種子育成實生苗，但一般之經濟栽培均不用之，而用分株法繁殖。

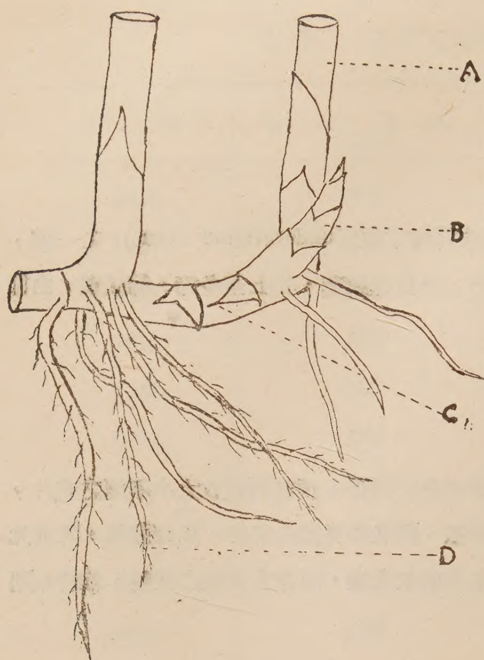



圖 1　三角藺之地下部

A莖　B芽　C根株　D根

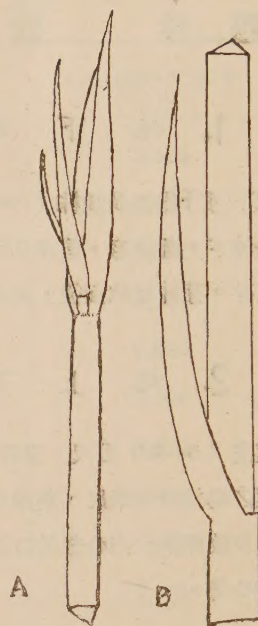



圖 2　三角藺之莖

A先端　B下端



圖 3　三角藺之花序

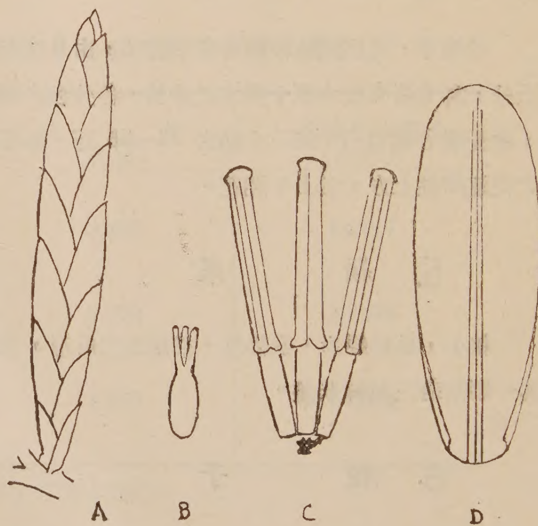



圖 4　三角藺之小穗及花

A小穗　B雌蕊　C雄蕊　D頴

## 五、氣候土宜

三角藺之生長習性，好高溫多日照而且富雨濕。在此理想氣候之下，其生長迅速，莖粗而長，品質佳。溫度低時生長慢，莖細而短，品質劣。若溫度過低，則其地下莖常致凍死。一般在生育前期宜有充分之水濕，收穫期宜高溫多晴天且無風害，因其莖較柔弱，暴風後，輕微者倒伏，嚴重者多折損，影響產量品質甚大。

三角藺最適宜之土壤為埴土乃至埴質壤土。於埴質壤土生長者，莖長而質地柔軟，產量品質均佳。於砂土或砂質壤土生長者，初期生長迅速，分蘖多，但後期發育不良，而容易枯死，且莖短而上下粗細不勻，質地粗硬。三角藺之抗鹹力强，在海濱地亦可栽培。但在鹹土上生長者，初期雨水多時生長迅速，至後期生長變慢，枯死莖多，因而莖短，品質劣，產量少。在排水不良之地栽培，則根細小，莖軟弱，先端易枯死，下端變黑，難得良好之品質。

## 六、栽　　培

### 1. 栽培制度

三角藺為宿根性之草本植物，其分蘖力强，宜行宿根栽培。通常一年收穫二次，有多至三次者。種植後頭次收穫者稱為新植草，其後每年於 4～6 月間收穫者稱為春草，於 9～11 月間收穫者稱為秋草。

### 2. 品　　種

岡山及大村地方，分為幼種及粗種二品種。幼種之特性分蘖多，莖稍圓而細短，品質優良，但產量少，對病蟲害之抵抗力弱，栽培較困難。粗種之分蘖較少，莖粗而長，品質尚佳，產量多，適應力較强，栽培容易，故栽培多。仁德地方分為大有種、硬骨種及猿種三品種。大有種之特性與粗種相似，是為實用栽培品種；其餘二品種與幼種相似，栽培極少。

### 3. 育　　苗

A. **苗田整地：**選擇搬運、管理、灌溉及排水方便，陽光充足，空氣流通，人畜之為害少而肥沃之埴質壤土為苗田。苗田整地與水稻同。於前作物收穫後灌水並犂耕土壤，以刈耙破碎土塊後，再以手耙耙平。每公頃本田需苗田 0.04～0.07 公頃。

B. **苗田種植：**三角藺以分株法繁殖。通常選生長良好，無病蟲害發生而雜草少之宿根田採取種苗。先由離根部約 50 公分處割去莖之先端，後以「割稻刀」或手挖出根部，洗淨附着之泥土，並除去雜草。約 100 莖縛成一束，置於蔭蔭處，根部暫浸在水中以便種植。種植期南部為 2 月或 10 月。株行距約為 30～45 公分，每叢 2～3 莖。種植時田裏保持淺水。育苗期間四個月。

C. **苗田管理：**種植後約一個月行第一次除草，以後視雜草發生情形酌行之。平常田裏保持水深 6～9 公分。雨季來臨時注意排水。

D. **苗田肥料：**不施用基肥。第一次除草後行第一次追肥，每公頃施用硫酸錏 200～500 公斤，再隔一個月左右行第二次追肥，肥料及施肥量與第一次同。

### 4. 整地及移植

整地與苗田整地同。本省栽培三角藺，亦有不育苗而直接由生長良好，雜草發生少之宿根田

採苗者。通常於移植前數天開始採苗。採苗時，苗田裏宜保持淺水。移植期南部爲 2 月或 7 月。株距 24～45 公分，行距 30～45 公分，每叢 3～5 莖。

### 5. 管　　理

移植後 3～4 週行第一次除草，此後視雜草發生情形酌行之。每於收割後即清除田內之枯死莖及雜草，約隔半個月，田間若有雜草發生即行除草。移植後 3～4 週間，田裏經常保持水深 6～9 公分，其後視天氣情形酌行灌溉與排水。生育期間經常保持濕潤狀態。田之四邊宜掘小環溝，便於灌溉排水。降大雨時田裏積水多，須及早排水，以免根部腐爛，莖頭變黑。春草與秋草之管理同上。

### 6. 肥　　料

本省栽培之三角藺通常不施基肥，追肥又單用氮肥，罕用磷肥及鉀肥。新植草於第一次除草後行第一次追肥，每公頃施用硫酸錏 200～500 公斤，隔一個月左右行第二次追肥，肥料及施肥量與第一次同。全省春草於 2～4 月間行 1～2 次追肥，每公頃之總施肥量爲硫酸錏 300～1000 公斤；秋草於 6～8 月間行第一次追肥，每公頃施用硫酸錏 300～500 公斤，於 8～9 月行第二次追肥，每公頃施用硫酸錏 240～400 公斤。施肥前排水並除草。收穫前一個月停止施肥。

### 7. 輪　　作

三角藺宿根數年後，生長勢力逐漸衰弱，雜草增多，因而產量與品質均降低。爲提高產量與品質，須要輪作。通常於移植後 5～8 年與水稻輪作一次。於第一期或第二期水稻插秧前將地上部割除後，以犂耕翻地下部，再用刈耙或鋤頭切碎並除去根株，最後耙平以便插秧。種 1～2 年水稻後，再種植三角藺。最近有用耕耘機整地者，其工作效率增倍。

## 七、收穫調製及品質

### 1. 收　穫　期

新植草於移植後 5～6 個月收穫。春草之收穫期，岡山及大村均爲 5 月，仁德爲 4 月。秋草之收穫期，岡山爲 10 月，仁德及大村爲 9 月。

### 2. 收穫及調製

於晴天男工用鎌刀由接近地面處收割，除去折損枯死莖與莖長不及 3 台尺 2 寸者，然後依莖之長度分爲五級。分級之標準爲 6 台尺 4 寸，5 台尺 8 寸，5 台尺 2 寸，4 台尺 6 寸，3 台尺 2 寸。分級後去梢置於陰涼處剖草，此工作由女工擔任。其方法以特製小刀剖莖爲大小均等之兩片。最近有以細鋼線裝在小箱上剖草者，其工作效率可提高 1.5 倍。剖草後暴曬，俟梢部乾燥後，將長度品質相同者結成小束，繼續曝曬，至莖基部完全乾燥爲止。陽乾後再依長度品質分級，將各級之小束打捆，每捆重約 60～90 公斤，貯藏於乾燥之處。

### 3. 產　　量

每公頃之乾草產量依產地及收穫期之不同而異。一般言之，春草之產量最高，秋草次之，新植草最低。據筆者調查岡山地方之春草最高產量每公頃 12,000 公斤，秋草 7,200 公斤；仁德地

方之春草最高產量每公頃達 18,000 公斤，秋草 12,000 公斤。岡山與仁德兩地，各期每公頃之平均產量如表 3。

表 3　每公頃平均乾草產量(公斤)

| 鄉鎮別＼期別 | 新植草 | 春草 | 秋草 |
|---|---|---|---|
| 岡山 | 4,800 | 7,800 | 5,400 |
| 仁德 | 8,400 | 10,200 | 9,000 |

### 4. 品質

依長度分爲 6 台尺 4 寸，5 台尺 8 寸，5 台尺 2 寸，4 台尺 6 寸，3 台尺 2 寸五級外，各級再予色澤、粗細、軟硬分爲下面三等。

**上等：**頭部白，其他鮮淡綠，有光澤，粗細及軟硬適宜。

**中等：**頭部白，其他淡綠，稍有光澤，粗細及軟硬中等。

**下等：**頭部黑或赤，其他黃或褐，無光澤，粗硬。

影響品質之因素爲氣候、土壤、肥料、管理、調製、病蟲害等。前二項已述及，不再贅言。三角藺生育期中，若施用適量之肥料，則產量及品質均佳。若施用氮肥過多，莖色暗綠而甚柔軟，品質不佳；反之，施肥量不足時，則莖細短而且硬，品質亦不佳。生育期中如排水不良，則頭部變黑。收穫調製時若遇雨不能曝曬，則草色變褐，品質惡劣，屬於下等品。患病蟲害時，品質亦受影響。通常春草之品質比秋草佳，但岡山低窪地所產之春草常比秋草差，因收穫期多雨，排水不良，頭部帶黑色。

## 八、病虫害

### 1. 病害

A.　**三角藺鱉甲病：**爲三角藺之主要病害，俗稱爲「黃肚」，其病原菌爲 Kawakamia Cyperi Miyabe。本病爲害莖及葉，發生於全生育期，被害嚴重者達 70～80 %。栽培於鹹性土者，較易發生此病。被害部初期生黃色小斑點，後逐漸擴大爲黃褐色不正形之鱉甲斑紋。一般容易由病斑處折斷而枯死。多濕氣時，病斑上生白粉狀之黴。防治法：(1) 速除去被害莖燒之。(2) 選酸性土栽培之。(3) 田地常保持濕潤，不可灌漑深水。(4) 避免過度或偏用氮肥，充分施用鉀肥。(5) 發生厲害時，撒布 4 斗式石灰倍量波爾多液 (Bordeaux mixture)。

B.　**三角藺煤病：**病原菌爲 Meliola sp.。被害莖之表面生黑色或煤色之黑粉狀病斑，至後期莖枯死。於岡山及仁德常發生此病，爲害頗大。本病之防治法同鱉甲病外，於發生初期可噴射下面之任何一種殺蟲藥：魚藤精乳劑 1,000～2,000 倍液，50% 馬拉松 (Malathion) 乳劑 2,000～3,000 倍液，怕拉松 (Parathion) 乳劑 1,000 倍液，PM 乳劑 1,000～4,000 倍液。因本病病菌寄於蚜蟲所分泌之糖蜜中，用以上殺蟲藥殺滅蚜蟲，本病自可除去。

C.　**三角藺軸黑穗病：**病原菌爲 Cintractia Peribebuyensis Sawada。初期在小花梗之基部

發生紡錘形之膨大物，被橙淡黃色之膜，其後剝離而露出黑粉塊。防治法同鱉甲病。

D. **三角藺銹病**：病原菌為 Uredo Cyperi-tagetiformis P. Henn.。於葉裏散生或集生稍橢圓形之夏胞子堆，破裂後散出濃褐色之粉狀胞子。防治法同鱉甲病。

### 2. 蟲　　害

A. **小蝗**（Oxya intricata Stal）：成蟲黃綠色，頭部略呈三角形，向前方突出，前胸背與頭部同寬，兩側有黑褐色之寬縱條紋。前翅細長，灰褐色；後翅寬而透明，翅脈黑色。體長包括翅端為 3.0～3.9 公分。幼蟲初孵化時為淡綠色，後綠色漸增深。食害葉及嫩莖。防治法：（1）捕殺成蟲及幼蟲。（2）移植前耕犁後灌水，收集並燒却浮於水面之蝗卵。（3）應用明溝遮斷法，以阻蝗蝻之移動。（4）噴 10% DDT粉劑或 1～1.5% γ—BHC 粉劑。

B. **小翅蝗**（Oxya japanica Willemse）：成蟲體長約 3～3.5 公分、黃綠色，頭胸部黃褐色，前胸有二褐色縱條紋，頭部圓，後脚大，翅短而不超過腹部末端。幼蟲之形狀與成蟲相似，但呈黃色乃至綠色，缺少斑紋。防治法與小蝗同。

C. **長翅蝗**（Oxya velox Fabricivs）：成蟲之形狀與小翅蝗相似，但翅較長，超過腹部末端。幼蟲之形狀及防治法與小蝗同。

D. **負蝗**（Atractomorpha ambigua Bolivar）：成蟲體長 2.8～4.0 公分，普通呈綠色，亦有呈灰褐色者。頭圓錐形，觸角短，前翅細而超過腹部末端，翅端尖。幼蟲全體綠色，形狀與成蟲相似，但缺少翅。防治法同小蝗。

E. **大白螟蛾**（Scirpophaga praelata Scopoli）：成蟲全體白色而有銀色光澤，翅長 1.2～1.5 公分。幼蟲頭黃白，全體暗黃色或黃白色，體長 2 公分左右。成蟲晝間靜止在葉上，晚間活動，產卵於葉上。幼蟲孵化後嚙入莖葉內部，使其枯死，屢屢有大害。防治法：（1）摘除卵塊及捕殺成蟲。（2）清除並燒却被害莖。（3）噴射富粒多（Folidol）乳劑 2,000～4,000 倍液或 PM 乳劑 2,000 倍液。

## 九、收支計算

### 1. 收　　入

因價格常有變化，故收入不能固定。依據筆者 1959 年 10 月 10 日（岡山）及 11 月 22 日（仁德）之調查，岡山與仁德二地，每公頃各期之平均收入概數如表 4。

表 4　每公頃之估計平均收入(元)

| 鄉鎮別 \ 期別 | 新植草 | 春草 | 秋草 |
|---|---|---|---|
| 岡山 | 9,600 | 15,600 | 10,800 |
| 仁德 | 15,000 | 18,000 | 16,000 |

### 2. 支　　出

據筆者之調查（日期與收入同），岡山及仁德二地，每公頃各期之平均支出概數如表 5。

表 5　每公頃之估計平均支出(元)

| 項目＼鄉鎮／期別 | 岡山 | | | 仁德 | | |
|---|---|---|---|---|---|---|
| | 新植草 | 春草 | 秋草 | 新植草 | 春草 | 秋草 |
| 苗 | 1,500 | — | — | 1,200 | — | — |
| 整地 | 420 | — | — | 500 | — | — |
| 移植 | 1,000 | — | — | 1,200 | — | — |
| 管理 | 700 | 550 | 550 | 1,400 | 1,200 | 800 |
| 收穫 | 2,800 | 4,550 | 3,150 | 5,600 | 6,800 | 6,000 |
| 肥料 | 1,340 | 1,000 | 1,800 | 3,200 | 3,200 | 2,300 |
| 地租 | 180 | 180 | 180 | 300 | 300 | 300 |
| 水租 | 330 | 330 | 330 | 300 | 300 | 300 |
| 戶稅 | 100 | 100 | 100 | 150 | 150 | 150 |
| 合計 | 8,370 | 6,710 | 6,110 | 13,850 | 11,950 | 9,850 |

註：地租、水租、戶租均[illegible]年份，岡山草田 14 期，仁德 10 期。仁德之工資較高，管理較精密，施肥量較多。

### 3. 純益

據表 4 及表 5，岡山與仁德，每公頃各期之平均純益概數如表 6。

表 6　每公頃之估計平均純益(元)

| 項目＼鄉鎮／期別 | 岡山 | | | 仁德 | | |
|---|---|---|---|---|---|---|
| | 新植草 | 春草 | 秋草 | 新植草 | 春草 | 秋草 |
| 收入 | 9,600 | 15,600 | 10,800 | 15,000 | 18,000 | 16,000 |
| 支出 | 8,370 | 6,710 | 6,110 | 13,850 | 11,950 | 9,850 |
| 純益 | 1,370 | 8,890 | 4,690 | 1,150 | 6,050 | [illegible],150 |

於岡山栽培水稻，1959 年每公頃之平均純益，第一期約為 3,500 元，第二期約為 2,000 元。若將岡山三角藺之純益與水稻比較，則可知春草與秋草之純益均比水稻高，而新植草較低。

## 十、今後改進三角藺栽培之要點

### 1. 提倡育苗

甚多草農不另設苗田育苗，而直接由宿根田採苗。此種苗，生長力及分蘖力均較弱。另設苗田育苗，所得之苗，生長力及分蘖力均較强。

## 2. 使用植物生長促進劑

本省之三角藺通常收穫二次，亦有三次者。如收穫三次，因生長期短，致影響品質，又每次之產量減低。如使用植物生長促進劑促進三角藺生長，可望一年收穫三次而不致影響品質，單位面積之年產量可以增加。奇拔靈（gibberellin）能促進植物生長，如用以處理三角藺，可能有實用價值。

## 3. 注意灌漑排水

岡山地區多栽培三角藺於低窪地，其灌漑排水均不便。夏季積水，致根部腐爛而枯死者甚多；不腐爛者生長受阻，莖下端變黑。冬季乾旱，因缺水而枯死者不少，生長亦受阻。目前急須擴建排水溝，增建灌漑工程。

## 4. 改進施肥法

栽培三角藺如欲得產量豐富，品質優良，在生長期中，須施用適量之肥料。本省之草農常過度或偏用氮肥，致蘗甲病及煤病之爲害猖獗，產量及品質受嚴重之影響。此種不合理之施肥法須改進，而施適量之氮肥、磷肥及鉀肥。兹舉日本大分縣之苗田、本田施肥量於表 7、表 8，供爲施肥之參考。

表 7 日本大分縣苗田每公頃施肥量(公斤)

| 肥料種類 | 總施肥量 | 基肥 | 第一次追肥 | 第二次追肥 |
|---|---|---|---|---|
| 堆肥 | 562.50 | 450.00 | — | 112.50 |
| 人糞尿 | 1,125.00 | 375.00 | 375.00 | 375.00 |
| 過磷酸鈣 | 18.75 | 18.75 | — | — |

表 8 日本大分縣本田每公頃施肥量(公斤)

| 肥料種類 | 總施肥量 | 基肥 | 七月下旬追肥 |
|---|---|---|---|
| 堆肥 | 7,000.00 | 7,000.00 | — |
| 菜籽粕 | 375.00 | 375.00 | — |
| 大豆粕 | 187.50 | — | 187.50 |
| 硫酸錏 | 375.00 | 225.00 | 150.00 |
| 過磷酸鈣 | 375.00 | 375.00 | — |
| 硫酸鉀 | 150.00 | 150.00 | — |

## 5. 奬勵使用耕耘機整地

栽培三角藺多年後，地表有一厚層之老根及根株。與水稻輪作時，若以牛犂翻耕，操作困難，工作效率低，頗費勞力；若以耕耘機代之，則操作輕易，工作效率高，節省勞力甚多。

### 6. 改進收穫及調製法

岡山之低窪地，春草收穫期多雨，因排水不良，頭部變黑。爲避免此弊，須於初春應盡早灌溉施肥，以便提早收穫。部份草農過於提早收穫，致品質及收量均降低，又曬草於道路上，草被人車踏壞，因而影響品質，故以上均須避免。以鋼線代替小刀割草，可提高 1.5 倍之工作效率，故應普遍使用之。由表 5 可知，除新植草外，收穫及調製之支出佔總支出之一半以上，將來若能發明機器用以收穫及調製，則可提高工作效率，支出必然減少甚多。

### 7. 推廣病蟲害之防治法

甚多草農不知如何防治病蟲害，致罹病蟲害時置之不顧，或防治不得法，因而產量與品質均受嚴重影響，故須急早推廣病蟲害之防治法於草農。

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# THE TRIANGIE RUSH IN TAIWAN

by

B. J. Lin

## SUMMARY

This paper describes about the production and economy of triangle rush in Taiwan.

Triangle rush is the most important plaiting and rough weaving crop in Taiwan, its stem used for the purpose of plaiting mat. Recently, it is also used for the purpose of plaiting a kind of rug which exports to the United States in large quantities, so the triangle rush manufacture is becoming one of the important manufactures in Taiwan.

Triangle rush was introduced in Taiwan from the mainland of China in former times. The distribution of the crop is limted in a way, Tainan, Kaohsiung and Changhwa prefectures are the chief producing districts. In 1958, its total planting area was 707 ha. and total yield was 8,024,062 kg.

Climatically most of the paddy lands in Taiwan are adapted to grow triangle rush. Recently the planting area and yield greatly increased to meet a demand of this crop, however, the problem lies on how to increase the unit area production and improve the quality of this crop. There are many defects must be improved on the method of cultivation, so the writer suggests some points for reference as follows:

1. Prepare a nursery to bring up healthy young plant.
2. Apply plant growth promoting substance to promote the growth and increase a number of harvesting times.
3. Enforce irrigtion and drainage for the benefit of growth.
4. Improve the application of fertilizers.
5. Use power tillers to prepare land.
6. Improve the method of harvesting and manufacture of the crop.
7. Enforce the diseases and insect pests control.

According to the latest investigation, which carried out by the writer in 1959, the economy of triangle rush is in the following:

| | |
|---|---|
| Estimate income (per hectare, N.T.$): | |
| 1st crop (harvested in spring) | 15,600–18,000 |
| 2nd crop (harvested in autumn) | 10,800–16,000 |
| Estimate cost: | |
| 1st crop | 6,700–12,000 |
| 2nd crop | 6,100– 9,900 |
| Estimate net profit: | |
| 1st crop | 6,000– 8,900 |
| 2nd crop | 4,700– 6,100 |

The estimate net profit per hectare of triangle rush is higher than the paddy rice by N.T.$ 2,700–6,900.

# COMPARATIVE STUDY ON AMOUNT OF SELECTION CUTTING OF MAKINO BAMBOO STAND

by

Yung-Kuen Fang

Makino bamboo (Phyllostachys Makinoi Hay.) is the most importance among many species of bamboos growing in Taiwan. It was widely used for the building materials, the pulpwood and making the bamboo-ware etc. It is distributed in low plains and mountain plateaus of the central and northern Formosa on heights 100 to 1,000 meters altitude.

The regeneration by subterranean shoots under selection system was adopted for this bamboo, so the bamboos over three years of age were usually removed by selection cutting, and the younger individuals were reserved. Consideration was given to the numbers of bamboo, the total basal area and the density of stem at the time of cutting. In the past no standard was determined for these cuttings. If too much cutting is done, it will reduce the amount of new bamboo shoots which can be produced in future because the forest land is easily laid bare, forest soils dry up, weeds and shrubs spread out tkickly. If the cutting is not enough, the reserved bamboos grow crowded, so that forest land has hardly any space for the bamboo shoots and the new bamboos will be a few in number and small in diameter. This study was carried out to determine the optimum degree of the reserved bamboos in a fixed area.

## MATERIALS AND METHODS

1. Experimental Situation: This study was conducted in the experimental forest of Taiwan Provincial College of Agriculture, at Tung-Shih, compartment No. 16. These experimental plots are located in the mountains at 320 meters above the sea-level, at the inclination of 10 degrees in a north-eastern direction. The soil belong to the type of sandy clay loam which contained a little humus on the surface layer.

2. Forest in General: The age of this Makino bamboo stand was from one to six years, the ages of the individual bamboo greatly varied. The d. b. h. (diameter of breast height) of the large ones were 5 to 7 centimeters and small ones were 2 to 3 centimeters. This stand consisted of bamboos growing closely together and hardly receiving any direct sun-light because no thinning had been done for a long time. Fallen-leaves lay very thick on the ground.

3. Methods: In mid-November, 1954, the two hectares rectangle of compartment No. 16 were selected for the experimental situation under the same site conditions. It was then divided into equal twenty plots along the vertical direction of a declivity arranged in five blocks and each block contained four plots. The area of each plot has 0.1 hectare. Stakes

were driven in the bounds of each plot to separate and distinguish it from the others. This experimental study was arranged according to the method of randomized block design and each treatment consisted of five replicates. The numbers of reserved bamboos in each plot were divided into four: 100, 300, 500 and 700, and the bamboos which were not reserved were cut out in mid-December 1954. The bamboos in each plot were reserved to a definite number, and the reserved bamboos were distributed equally throughout that plot. The trunks of the reserved bamboos were painted with distinctive colors for each plot, e. g. in one plot the trunks were painted red, in an adjacent plot the color were white etc. The d. b. h. of the reserved bamboos measured at the same time is given below in Fable 1.

Table 1. Total Basal Areas of Reserved Bamboos (unit: sq. cm)

| Reserved Nrs. / Block | 100 | 300 | 500 | 700 | Total |
|---|---|---|---|---|---|
| I | 1854.3088 | 3955.9476 | 6829.8294 | 7749.8351 | 20389.9209 |
| II | 1480.3424 | 3815.9657 | 6024.0368 | 8206.2697 | 19526.6146 |
| III | 1934.8700 | 3994.0521 | 6966.7184 | 9722.9136 | 22618.5541 |
| IV | 2104.7990 | 4762.1869 | 7593.5095 | 7440.0852 | 21900.5806 |
| V | 1290.8370 | 3027.6707 | 4623.3787 | 7395.0742 | 16341.9606 |
| Total | 8665.1572 | 19555.8230 | 32042.4728 | 40514.1778 | 100777.6308 |

4. Survey and Observations: In Spring of 1955, there were very few bamboo shoots coming up in all plots because of lack of the rain. Therefore the survey was not made then, and experimental plots were simply weeded. This was only a few months after cutting out the non-reserved bamboos. In mid-October 1956, the numbers of new bamboos and their diameter of breast-height were determined and the results were put to use in a statistical study.

## RESULTS AND ANALYSES

1. Numbers of New Bamboos and their d. b. h. : The new bamboos which came up in Spring of 1955 and 1956 were surveyed for this experimental study in October, 1956. The results are found in Tables 2 and 3 as follows

2. Analysis of Covariance: The price of bamboos is calculated with the unit of a bunch in such a way that the larger the number of bamboos in a bunch the smaller diameter of each bamboo and conversely the smaller the number in a bunch the greater the diameter of each bamboo. However since the unit of a bunch has not been standardized here in Formosa markets, it is hard to make accurate comparisons of production in different

Table 2. Number of New Bamboos

| Block \ Reserved Nrs. | 100 | 300 | 500 | 700 | Total |
|---|---|---|---|---|---|
| I | 332 | 166 | 157 | 122 | 777 |
| II | 158 | 158 | 151 | 137 | 604 |
| III | 200 | 153 | 140 | 126 | 619 |
| IV | 220 | 167 | 162 | 127 | 676 |
| V | 161 | 122 | 141 | 110 | 534 |
| Total | 1071 | 766 | 751 | 622 | 3210 |

Table 3. Total d. b. h. of New Bamboos (unit: cm.)

| Block \ Reserved Nrs. | 100 | 300 | 500 | 700 | Total |
|---|---|---|---|---|---|
| I | 840.1400 | 471.1500 | 549.1000 | 484.7900 | 2345.1800 |
| II | 403.9600 | 444.9000 | 503.3600 | 520.3400 | 1872.5800 |
| III | 524.7400 | 400.9700 | 461.7800 | 439.7000 | 1827.1900 |
| IV | 595.8600 | 448.5300 | 470.1900 | 333.7300 | 1847.3100 |
| V | 422.0800 | 320.6400 | 367.8800 | 304.5400 | 1415.7400 |
| Total | 2787.4000 | 2086.1900 | 2352.3100 | 2082.1000 | 9308.0000 |

localities. Thus we can not use the unit of a bunch in this study.

Tables 2 and 3 show that the number of new bamboos is inversely proportional to the number of reserved bamboos. However Table 3 shows the total d. b. h. at each plot is not definitely in proportion to the number of reserved bamboos. We know that is excellent to produce many new bamboos with large d. b. h. It is really a difficult matter to compare the good and the bad points of each treatments, so the results in Tables 2 and 3, were adopted for analysis of covariance.

Let us assume that X is the numbers of new bamboos and Y is the d. b. h. at each new bamboo. When the analysis of variance begins, X of each plot was reduced by the mean of 100 and Y was reduced by the mean of 300. Table 4 gives the results of this analysis. F test got significant results at 1 percent level, it must then be compared with multiple range test.

Tadle 4. Analysis of Variance and Covariance of the Numbers of New Bamboos and their Total d. b. h.

| Variance | Degree of freedom | Sums of squares & products | | | Adjusted erros | | | F values | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SX²① | Sxy② | SY²③ | Sum of squares | Degrees of freedom | Mean squares | Observed | Required 5% | Required 1% |
| Total | 19 | 43939.0000 | 36392.2900 | 257928.1062 | | | | | | |
| Blocks | 4 | 8254.5000 | 28331.1275 | 108537.3922 | | | | | | |
| Treatments | 3 | 21731.4000 | 35061.5900 | 66114.8444 | | | | 13.7722** | 3.59 | 6.22 |
| Error | 12 | 13953.1000 | -27000.4275 | 83275.8696 | 31027.7609 | 11 | 2820.7055 | | | |
| Treatments error | 15 | 35684.5000 | 8061.1625 | 149390.7140 | 137569.6898 | 14 | 10540.6921 | | | |
| Adjusted error | | | | | 116541.9289 | 3 | 38847.3096 | | | |

Note: ** =Significant at 1 percent level.

①$SX^2 = S(X-\overline{X})^2$

②$Sxy = S(X-\overline{X})(Y-\overline{Y})$

③$SY^2 = S(Y-\overline{Y})^2$

The regression equation will be of the form

$$\hat{\overline{Y}}_1 = \overline{Y}_1 - bxy(\overline{X}_1 - \overline{X})$$

Where $\hat{\overline{Y}}_1$ is the adjusted mean for $\overline{Y}_1$, $\overline{X}_1$ is the mean of X for reserved 100, $\overline{Y}_1$ is the mean of Y for the same treatment, bxy is the regression of Y on X in the error line.

The predicted means of d. b. h. were calculated by above regression equation as given in Table 5.

Table 5. Observed Multiple Range Values

| Reserved Nrs. (X) | Adjusted means of d. b. h. (Y) | Differences | | |
|---|---|---|---|---|
| 100 | 661.3948 | | | |
| 500 | 450.5305 | 210.8643** | | |
| 300 | 403.1118 | 258.2830** | 47.4187 | |
| 700 | 346.5629 | 314.8319** | 103 9676 | 56.5489 |

**=Significant at 1 percent level.

3. Multiple Range Test: Finney's formula is used for this multiple range test as follows:

$$S^2(\hat{Yr}) = \frac{S^2}{r}\left(1 + \frac{A}{A(t-1)}\right)$$

$$S(\hat{Yr}) = \pm\sqrt{1650.7896}$$

$$= \pm 40.6299$$

Where $S^2(\hat{Yr})$ is adjusted mean square for errors, $S(\hat{Yr})$ is adjusted standard error, $A_2$ is the adjusted sum of squares for the errors, $A_1$ is the treatment sum of squares for X, r is the number of replications, and t is the number of treatments.

$$R_{4(0.05)} = R_{(4,12,0.05)} \times 40.6299 = 3.33 \times 40.6299 = 135.2946$$
$$R_{3(0.05)} = R_{(3,12,0.05)} \times 40.6299 = 3.23 \times 40.6299 = 131.2346$$
$$R_{2(0.05)} = R_{(2,12,0.05)} \times 40.6299 = 3.08 \times 40.6299 = 125.1401$$
$$R_{4(0.01)} = R_{(4,12,0.01)} \times 40.6299 = 4.68 \times 40.6299 = 190.1479$$
$$R_{3(0.01)} = R_{(3,12,0.01)} \times 40.6299 = 4.55 \times 40.6299 = 184.8660$$
$$R_{2(0.01)} = R_{(2,12,0.01)} \times 40.6299 = 4.32 \times 40.6299 = 175.5212$$

The above testing result shows that the treatment of 100 was better than treatment other numbers of reserved bamboos tried. The differences were all significant at 1 percent level as shown in Table 5.

## DISCUSSION

It appeats from this survey and analysis that the numbers of reserved bamboos were optimum when a 100 individuals were reserved in the unit area of 0.1 hectare for the regeneration of Makino bamboo stand. This treatment not only produces more new bamboos than others, but its total d. b. h. of each plot was larger than that of any plots of the other treatments. After covariance analysis, we know that best results in numbers and d. b. h. are produced on plots at 100 reserved bamboos, and the other three treatments namely at 300, 500 and 700 produce inferior rerults. The other three treatments tried out did not produce any significant results. Increasing the reserved numder to 300 influence adversely the number of new bamboo shoots and its diameter.

Why do lower reserved numbers produce better results? The subterranean shoots are not crowded, reserved parent bamboos receive more sunlight, soil moisture and nutrition, etc., and much space increasing their productiveness. Greater space allows new bamboo shoots to come up without any obstacle to their growth. Thus new bamboos are in greater number and have a larger d. b. h. than they otherwise would.

If a bunch is the unit used for marketing, a greater number of bunches is produced by the treatment of 100 reserved bamboos than by the other treatments. This study shows that it is more profitable to cut many and to reserve but a few in the very beginning. The more cuttings that are made, the better results are obtained.

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## (中 文 摘 要)

# 桂竹林分擇伐量之比較試驗

方 榮 坤

臺灣省立農學院實驗林管理處東勢林場第十六林班，民國四十三年十一月中旬擇伐桂竹之際，因慮單位面積上保留株數之多寡不同，將來必影響新竹發生之株數及其直徑大小。遂擇傾斜度10°，方位向東北之試驗地 2 公頃，等分爲 20 試區，即每試區 0.1 公頃，保留株數分100, 300, 500 及 700 株等四種處理，並分五區集隨機排列之。

擇伐後約達二年之久，即至民國四十五年十月中旬調查兩個春季所產之新竹株數及其胸徑，經變方及變積分析後，各處理之 F 值極爲顯著，再經多種變域測驗，結果以保留 100 株者爲最優，其餘處理 300, 500 及 700 株之間，既無顯著差異，且均遠較 100 株者爲劣。故知 0.1 公頃之林地面積上宜保留100株，超出之數悉擇伐之；否則母竹過多，林地既鮮空隙，難以發筍出土；又因地下根莖擁擠，影響其所產新竹之直徑亦小。

# 麻六甲合歡·鐵刀木·柚木及印度黃檀之生長比較研究

林 子 玉

# Comparative Studies on the Increments of East India Walnut, Siamese Senna, Teak and Sissoo in Shin-Hua Forest Experimental Station.

by
Tzu-Yu Lin

## 一、緒 言 (Introduction)

麻六甲合歡屬含羞草科（Mimosaceae），合歡屬（Albizzia Durazz），學名為 Albizzia falcata Bacher，日名モルツカネム，英名為 East India Walnut；原產地為南洋麻六甲，安門尼亞，及班達諸島；約於民國17年（1927），由日人自馬來麻六甲半島引進種植在本省，但未經推廣造林，為本省尚屬罕見稀少樹種。該樹為常綠大喬木，無論在原產地或引進種植地之臺灣，其生長迅速，如在原產地種植後2年之樹高達到30英尺，胸高直徑24英寸，實較任何樹種之生長為迅速，在臺灣之生長，雖略遜於原產地，但其他濶葉樹造林樹種，罕見鮮有如此迅速，無與比擬。

鐵刀木屬蘇木科（Caesalpiniaceae），鐵刀木屬（Cassia Linn），學名為 Cassia Siamea Lam，日名稱タガヤサン，英名為 Siamese senna, 或 Bombay brack wood, Rose wood；原產於緬甸、泰國、馬來半島及印度等地；約於民國前11年（1920）引進種植於臺灣，自民國8年（1919），由日政府採為造林樹種之一，種植於高雄一帶，以後逐漸推廣至臺灣中南部低海拔地區，因造林容易，生長迅速，喬林矮林均易經營，木材硬重堅强之故，現為臺灣引進主要造林樹種之一。

柚木屬馬鞭草科（Verbenaceae），柚木屬（Tectona Linn），學名為 Tectona grandis Linn，日名稱チーク，麻栗，英名為 Teak；落葉喬木，樹皮淡褐色或淡灰色，纖維質狀淺縱裂，質薄而易剝落；原產地南洋、爪哇、泰國、越南、緬甸各地；在民國前12年（1901）引進臺灣種植海拔600公尺以下之處，而大獲成功，與原產地之生長不相上下，亦能行萌芽更新，木材用途甚廣，且不腐蝕，能抵抗海陸動物之蝕害，為熱帶用材主要樹種之一，現今在嘉義以南，海拔600公尺以下之無風害地帶均可造林，為臺灣山麓之主要造林樹種。

印度黃檀屬蝶形花科（Papilionaceae），黃檀屬（Dalbergia Linn.f），學名為 Dalbergia Sisso Roxb，日名稱シツソノキ，英名為 Sissoo；落葉喬木，原產印度，係於民國前16年（1897），由日人自印度孟買引進臺灣，數十年來，於臺灣雖未被採用為大規模之經濟造林樹種，但在省內各地多有小規模之栽培，生長亦良好，且其樹性耐瘠耐乾，能抗風之故，可供荒山復舊造林及造成二期森林之樹種，而取代部份相思樹。

近年來，臺灣人口之激增，用材及薪材之需要，逐年劇增，為應付此項龐大的需要量，自不能專注重於天然林之開發，應講求積極造林之策，而樹種之選定尤關切要，林木之生產期間過長

久，迄其能供利用，短者拾餘年，長者達幾拾年之久，選擇生長迅速，材質良好之造林樹種，乃是林業之當前要務，且為林業經營上之基本方針，故造林容易，不擇土壤，幹形通直，生長迅速之如上各樹種，均適於推廣也。

茲為明瞭生育在同一林地上之諸種外來引進熱帶樹種之生長狀況，及其樹種間生長之差異，以供今後各樹種推廣造林及經營上之參考為目的，採取同一產於臺南縣新化鎮，新化林場第4.林班之造林木為材料，加以整理分析，草率成文，又因時間及材料有限，未能作更詳盡之研究，深感遺憾，文中誤謬之處，在所難免，倘希林業界先進多賜指教是幸！

本文之材料，野外調查工作承新化林場各同仁之協助，衷心於此誌謝。

## 二、調查方法　(Investigation Method)

本文供試材料，同產於臺灣省立農學院新化林場第4林班之麻六甲合歡柚木印度黃檀及第9林班鐵刀木之各造林地；在各造林地選擇標準區，並由其立木生長中傭者，隨機採取標準木各三株充供生長比較之材料。

將選出各樹種各三株之供試木，砍伐後按 Huber 氏區分法實施樹幹解析，查定樹高、胸高直徑、胸高斷面積及材積等之各種生長量，並依複利算式（Leibnitz 氏式）$P=\left(\sqrt[n]{\frac{M}{m}}-1\right)\times100$ 而計算材積生長率分別比較之。總生長及平均生長，依各樹種三株平均值，以普通觀察法比較之，連年生長，則分別按複合試驗分析法比較之，為統計方便計，樹高取用1～15年生間，材積取用2～15年生間，其餘取用3～15年生間之生長量。在取樣原則上，標本株數似嫌過少，恐不足以為該地之共同代表，但事實上，所選定之供試林木，尚屬生長中傭可代表該林分之一般生長，故藉此尚可察知該樹種之生長概況。

## 三、生長量比較　(Comparation of the increment)

### I　總生長量　(Total increment)

四樹種之供試木各三株，經樹幹解析後，分別查定各因子之總生長量，以其平均值加以觀察比較之。　茲列其結果如第1表：

綜觀第1表之結果，各因子之生長，於幼時，麻六甲合歡確較大為其他三樹種，其次為柚木，而印度黃檀則最劣，乃至15年生間，除材積生長率以印度黃檀稍示大外，餘各因子之生長量，均以麻六甲合歡為最優，反之，印度黃檀示最劣。

茲謹分別論述其差異如下：

(a) 樹高總生長量：麻六甲合歡之樹高總生長量始終凌駕其他三樹種，柚木雖較鐵刀木稍有優，但兩者相近可不分上下，以印度黃檀為最劣；當10年生時之麻六甲合歡生長量，已達到柚木之1.44倍，鐵刀木之1.45倍，印度黃檀之2.26倍，又柚木、鐵刀木之生長量為印度黃檀之1 56倍；當15年生時，麻六甲合歡之樹高竟達到24.3公尺，超出柚木之高7.49公尺，鐵刀木之7.63公尺，高出印度黃檀竟達13.95公尺；依此可知麻六甲合歡與柚木及鐵刀木之等量樹高生長需要年數約差6年，與印度黃檀即相差有10年之多。

(b) 胸高直徑總生長量：印度黃檀之胸高直徑總生長量始終落後，而以麻六甲合歡為最優，至12年生間柚木雖較鐵刀木為優，但以後即相反之；當10年生時之麻六甲合歡大約為柚木之1.5倍，鐵刀木之1.7倍，印度黃檀之2.6倍，然柚木有鐵刀木之1.1倍，印度黃檀之1.7倍；迄15年生時，麻六甲合歡確大鐵刀木10.18公分，更大印度黃檀14.13公分，但鐵刀木僅大於柚木0.94公分；故可知麻六甲合歡與印度黃檀之等量胸高直徑生長需要年數約有8年之差，與鐵刀木或柚木，有6年之差。

各因子總生長量比較表　　第 1 表

(Tab.1)　Comparison of the total increment of D.B.H, Basal area, Height, Volume, and Volume Percent.

| 樹齡（年） | 胸高直徑 (cm) | | | | 胸高斷面積 (m²) | | | | 樹高 (m) | | | | 材積 (m³) | | | | 材積生長率 (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 麻六甲合歡 | 鐵刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鉄刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鉄刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鉄刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鉄刀木 | 柚木 | 印度黃檀 |
| 1 | 1.45 | | | | 0.000180 | | 0.000000 | | 1.27 | 0.91 | 0.94 | 1.24 | 0.000152 | 0.000039 | | 0.000031 | | | | |
| 2 | 2.72 | | 2.00 | 0.76 | 738 | 0.000300 | 390 | 0.000045 | 3.14 | 1.99 | 3.13 | 2.53 | 1912 | 380 | 0.000964 | 153 | 1177.63 | 1136.70 | | 425.26 |
| 3 | 4.46 | 2.30 | 3.37 | 1.32 | 1736 | 426 | 991 | 139 | 5.54 | 3.45 | 4.50 | 3.30 | 6618 | 1336 | 2797 | 395 | 240.78 | 340.20 | 247.94 | 160.45 |
| 4 | 6.40 | 3.89 | 4.68 | 1.88 | 3594 | 1194 | 1791 | 282 | 7.74 | 5.38 | 5.72 | 4.13 | 18654 | 3638 | 5713 | 910 | 181.87 | 175.43 | 131.96 | 129.34 |
| 5 | 9.39 | 5.00 | 6.10 | 2.87 | 7351 | 1965 | 3073 | 514 | 10.04 | 6.73 | 6.92 | 4.68 | 43003 | 6723 | 11024 | 1675 | 130.53 | 86.17 | 87.78 | 85.64 |
| 6 | 10.99 | 5.73 | 7.37 | 3.41 | 9988 | 2717 | 4493 | 928 | 11.96 | 8.56 | 7.85 | 5.28 | 63248 | 12352 | 18119 | 3060 | 47.06 | 81.12 | 61.29 | 84.52 |
| 7 | 12.59 | 6.99 | 8.59 | 4.24 | 13117 | 3856 | 6090 | 1433 | 13.28 | 9.79 | 9.84 | 6.14 | 92573 | 20080 | 27341 | 5017 | 46.37 | 59.60 | 50.65 | 63.78 |
| 8 | 14.83 | 8.14 | 9.94 | 5.25 | 17782 | 5276 | 8049 | 2209 | 14.81 | 10.68 | 10.89 | 7.14 | 133410 | 32393 | 40251 | 8000 | 44.11 | 61.21 | 53.91 | 59.65 |
| 9 | 16.48 | 9.56 | 11.36 | 6.33 | 21830 | 7324 | 10428 | 3200 | 17.14 | 11.35 | 11.86 | 7.74 | 178744 | 50204 | 56528 | 11835 | 33.98 | 50.92 | 43.19 | 45.03 |
| 10 | 18.69 | 10.91 | 12.53 | 7.30 | 27851 | 9545 | 12592 | 4256 | 18.72 | 12.93 | 13.04 | 8.29 | 240913 | 63203 | 73310 | 16166 | 34.78 | 28.63 | 32.47 | 37.31 |
| 11 | 20.75 | 12.19 | 13.42 | 8.41 | 34074 | 11882 | 14364 | 5634 | 20.11 | 13.52 | 14.17 | 8.72 | 322888 | 82295 | 88426 | 20675 | 34.03 | 32.45 | 22.10 | 41.03 |
| 12 | 22.20 | 13.74 | 14.21 | 9.57 | 38913 | 15115 | 16033 | 7266 | 21.75 | 15.02 | 15.05 | 9.11 | 398119 | 104798 | 104203 | 30476 | 23.30 | 29.05 | 18.41 | 34.95 |
| 13 | 23.96 | 14.87 | 14.86 | 10.72 | 45157 | 17632 | 17400 | 9097 | 22.32 | 15.70 | 16.08 | 9.54 | 482149 | 128190 | 118239 | 39835 | 21.11 | 22.72 | 13.76 | 31.02 |
| 14 | 25.49 | 16.08 | 15.40 | 11.97 | 51039 | 20641 | 18795 | 11302 | 23.73 | 16.18 | 16.60 | 10.01 | 582094 | 154543 | 131538 | 50592 | 20.73 | 21.75 | 11.40 | 30.45 |
| 15 | 27.09 | 16.91 | 15.97 | 12.96 | 57685 | 22798 | 20177 | 13243 | 24.30 | 16.67 | 16.81 | 10.35 | 687038 | 178735 | 149352 | 61995 | 18.03 | 15.44 | 13.92 | 22.47 |

（c）**胸高斷面積總生長量**：麻六甲合歡之胸高斷面積總生長量示最大，反之，印度黃檀示為最劣；當10年生時之麻六甲合歡為柚木之2.2倍，印度黃檀之6.5倍，柚木僅為鐵刀木之1.3倍；及至15年生時之麻六甲合歡已超出鐵刀木之生長量 0.034887 $m^2$，柚木為 0.03750 $m^2$，印度黃檀有 0.044442 $m^2$ 之大，除麻六甲合歡之生長迅速外，鐵刀木與柚木之等量生長量，僅需1個年，而與印度黃檀約有3年，柚木與印度黃檀之間，只需2個年。

（d）**材積總生長量**：當5年生時之麻六甲合歡材積總生長量，既較大柚木之 3.9倍，鐵刀木之6.4倍，且示大為印度黃檀之25.7倍以上，然柚木為鐵刀木之 1.64倍，印度黃檀之6.58倍；當10年生時之麻六甲合歡大為柚木之3.28倍，印度黃檀之 4.53 倍，至13年生時鐵刀木與柚木之生長相類似，迄15年生時，麻六甲合歡確大印度黃檀，竟達11.1倍之多，而為柚木之4.6倍，鐵刀木之3.85倍，其等量材積之生長，鐵刀木與印度黃檀需時約6年之久，與柚木者，約有3年之差。

（e）**材積生長率**：最初5年間之麻六甲合歡材積生長率示甚大，但自6年生以後，即示不如鐵刀木或印度黃檀之大，於6～9年生間，柚木示較大麻六甲合歡，然11年生以後，反之，示較小為麻六甲合歡；當15年生時之麻六甲合歡材積生長率示18.03%，柚木13.92%，鐵刀木 15.44%，印度黃檀22.47%；若按 Pressler 氏法100/a測驗之，四樹種之材積生長率均較7%為大，則證明其材積之生長仍在旺盛時期。

## Ⅱ　平均生長量　(Mean annual increment)

前述各因子之總生長量查定後，復分別依 $Q=\frac{zm}{m}$ 求出各樹齡之平均生長量，分別以其各三株供試木之平均值而觀察比較之，茲列其結果如第2表：

綜觀第2表結果，各因子平均生長量，印度黃檀均較他三種為小，反之，麻六甲合歡為最優，茲就按其生長曲線之變化（圖略）說明其生長徑路如下：

（a）**樹高平均生長量**：麻六甲合歡以4～7年生為最優時期，以後稍有下降，但 9～10 年生時，尋有緩慢上升之傾向，以後即將緩慢下降，然均優於其他三樹種之生長；鐵刀木以6～7年生為生長旺盛時期，但過後就漸緩下降，其生長較遜為柚木，但其差異甚微；柚木以初年生長最大，至7～8年生後，逐漸下降，印度黃檀亦以初年之生長較大，而至晚年即顯有一直下降之趨勢，且示其生長較劣。

（b）**胸高直徑平均生長量**：麻六甲合歡自幼年緩慢上升到達11年生時生長量達最高，以後即示漸緩下降，且成起伏不平之坡浪式生長曲線，其平均生長量為其他三樹種均所莫及者；鐵刀木亦自幼年逐漸穩緩上升，而至11年生時到達最高；柚木在 5～11 年間之生長曲線成一圓弧形狀，以8，9兩年生時為最大，以後將下降遞減；印度黃檀之生長曲線成一直線狀，而徐徐上升未見有下降之趨勢。

（c）**胸高斷面積平均生長量**：麻六甲合歡等四樹種之生長，均呈直線上升生長徑路，以麻六甲合歡之生長示為最優，其次，共有年時之柚木見優，然至12年生以後，鐵刀木之生長將超出柚木之生長量，印度黃檀之生長示為最緩慢。

（d）**材積平均生長量**：四樹種均呈直線上升之傾向而增加，迄15年生時均未見其下降，就中麻六甲合歡最迅速最大，即於10年生時，為鐵刀木之3.8倍，柚木之3.28倍，印度黃檀之14.9倍之大，柚木有印度黃檀之4.53倍，鐵刀木為印度黃檀之3.11倍，至12年生之鐵刀木已凌駕柚木之上矣；當15年生時之麻六甲合歡已達鐵刀木之3.85倍，柚木之4.59倍，印度黃檀之11.08倍之大，而鐵刀木為印度黃檀之 2.87倍。依如前述材積生長率而言，麻六甲合歡等四樹種之生長，由此亦可證明其生長量尚在繼續增大，生長尚在旺盛時期。

各因子平均生長量比較表　第 2 表

(Tab. 2)　Comparison of the mean annual increment of D.B.H, Basal area, Height and Volnme.

| 樹齡(年) | 胸高直徑 (cm) | | | | 胸高斷面積 (m2) | | | | 樹高 (m) | | | | 材積 (m3) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 麻六甲合歡 | 鐵刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鐵刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鐵刀木 | 柚木 | 印度黃檀 | 麻六甲合歡 | 鐵刀木 | 柚木 | 印度黃檀 |
| 1 | 1.45 | | | | 0.000180 | | | | 1.24 | 0.91 | 0.94 | 1.24 | 0.000152 | 0.000039 | | 0.000028 |
| 2 | 1.36 | | 1.00 | 0.38 | 339 | | 0.000187 | 0.000023 | 1.57 | 1.00 | 1.57 | 1.27 | 971 | 191 | 0.000649 | 77 |
| 3 | 1.49 | 0.76 | 1.12 | 0.44 | 579 | 0.000142 | 330 | 46 | 1.85 | 1.15 | 1.50 | 1.10 | 2206 | 445 | 763 | 132 |
| 4 | 1.60 | 0.97 | 1.16 | 0.47 | 899 | 298 | 448 | 71 | 1.94 | 1.34 | 1.43 | 1.03 | 4664 | 910 | 1428 | 228 |
| 5 | 1,88 | 1.00 | 1.22 | 0.51 | 1470 | 393 | 615 | 103 | 2.01 | 1.35 | 1.38 | 0.93 | 8601 | 1344 | 3305 | 335 |
| 6 | 1.83 | 0.97 | 1.23 | 0.57 | 1665 | 453 | 749 | 155 | 1.99 | 1.43 | 1.14 | 0.88 | 10541 | 2059 | 3020 | 510 |
| 7 | 1.80 | 1.00 | 1.23 | 0.61 | 1731 | 551 | 870 | 205 | 1.90 | 1.40 | 1.41 | 0.87 | 13225 | 2868 | 3906 | 717 |
| 8 | 1.85 | 1.02 | 1.25 | 0.66 | 2223 | 660 | 990 | 243 | 1.85 | 1.33 | 1.36 | 0.89 | 16676 | 4056 | 5050 | 1000 |
| 9 | 1.83 | 1.06 | 1.26 | 0.70 | 2426 | 814 | 1159 | 356 | 1.90 | 1.30 | 1.32 | 0.86 | 19860 | 5578 | 6285 | 1315 |
| 10 | 1.87 | 1.09 | 1.25 | 0.73 | 2785 | 955 | 1259 | 426 | 1.87 | 1.29 | 1.30 | 0.83 | 24091 | 6320 | 7331 | 1616 |
| 11 | 1.89 | 1.11 | 1.22 | 0.76 | 3038 | 1080 | 1306 | 512 | 1.83 | 1.23 | 1.29 | 0.79 | 29353 | 7481 | 8039 | 2061 |
| 12 | 1.85 | 1.14 | 1.18 | 0.80 | 3243 | 1260 | 1336 | 606 | 1.81 | 1.25 | 1.26 | 0.76 | 33176 | 8733 | 8683 | 2540 |
| 13 | 1.84 | 1.14 | 1.14 | 0.83 | 3473 | 1356 | 1346 | 666 | 1.72 | 1.21 | 1.24 | 0.73 | 37088 | 9861 | 9091 | 3065 |
| 14 | 1.81 | 1.15 | 1.10 | 0.86 | 3646 | 1474 | 1320 | 807 | 1.69 | 1.16 | 1.19 | 0.71 | 41578 | 11039 | 9399 | 3614 |
| 15 | 1.81 | 1.13 | 1.06 | 0.87 | 3846 | 1520 | 1345 | 883 | 1.62 | 1.11 | 1.12 | 0.69 | 45803 | 11876 | 9963 | 4133 |

## Ⅳ　連年生長量　(Current annual increment)

四樹種各因子之連年生長量分別按複合試驗分析法比較其優劣。玆就各因子連年生長分別論述如下：

樹高連年生長量表　單位：m　第 3 表

(Tab, 3)　Current annual increment of height

| 樹齡（年） | 麻六甲合歡 | | | | 鐵刀木 | | | | 柚木 | | | | 印度黃檀 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ⅰ | Ⅱ | Ⅲ | 平均 | Ⅰ | Ⅱ | Ⅲ | 平均 | Ⅰ | Ⅱ | Ⅲ | 平均 | Ⅰ | Ⅱ | Ⅲ | 平均 |
| 1 | 0.66 | 1.56 | 1.60 | 1.27 | 0.26 | 1.18 | 1.30 | 0.91 | 1.23 | 1.30 | 0.30 | 0.94 | 1.30 | 1.12 | 1.30 | 1.24 |
| 2 | 1.35 | 1.56 | 2.68 | 1.86 | 0.65 | 1.35 | 1.22 | 1.07 | 1.80 | 1.83 | 2.93 | 2.19 | 1.22 | 1.48 | 1.18 | 1.29 |
| 3 | 3.88 | 0.68 | 2.66 | 2.41 | 1.75 | 1.87 | 0.78 | 1.47 | 0.97 | 1.87 | 1.27 | 1.34 | 0.78 | 0.70 | 0.82 | 0.77 |
| 4 | 2.17 | 2.18 | 2.24 | 2.20 | 2.14 | 2.40 | 1.16 | 1.90 | 1.00 | 1.86 | 0.80 | 1.22 | 0.70 | 0.50 | 1.30 | 0.83 |
| 5 | 1.62 | 3.46 | 1.82 | 2.30 | 1.40 | 1.87 | 0.84 | 1.37 | 1.30 | 1.30 | 1.00 | 1.20 | 0.53 | 0.47 | 0.70 | 0.57 |
| 6 | 1.80 | 2.02 | 1.93 | 1.92 | 1.10 | 1.76 | 2.63 | 1.83 | 1.00 | 0.80 | 0.99 | 0.93 | 0.63 | 0.47 | 0.70 | 0.60 |
| 7 | 0.48 | 2.05 | 1.44 | 1.32 | 1.93 | 1.27 | 0.47 | 1.22 | 3.03 | 0.94 | 2.01 | 1.99 | 1.61 | 0.51 | 0.46 | 0.86 |
| 8 | 1.87 | 1.95 | 0.79 | 1.54 | 1.89 | 0.30 | 0.48 | 0.89 | 0.62 | 0.66 | 1.86 | 1.05 | 0.59 | 1.14 | 1.26 | 1.00 |
| 9 | 2.84 | 2.10 | 2.04 | 2.33 | 2.18 | 0.43 | 0.42 | 1.01 | 0.98 | 0.74 | 1.19 | 0.97 | 0.52 | 0.81 | 0.48 | 0.60 |
| 10 | 1.42 | 1.95 | 1.38 | 1.58 | 1.26 | 0.49 | 2.00 | 1.25 | 1.37 | 1.23 | 0.95 | 1.18 | 0.45 | 0.33 | 0.88 | 0.55 |
| 11 | 1.99 | 0.18 | 2.01 | 1.39 | 0.67 | 0.38 | 0.72 | 0.59 | 1.20 | 0.77 | 1.40 | 1.12 | 0.50 | 0.22 | 0.56 | 0.43 |
| 12 | 1.69 | 1.87 | 1.35 | 1.64 | 1.29 | 2.30 | 0.91 | 1.50 | 0.80 | 1.26 | 0.60 | 0.89 | 0.46 | 0.33 | 0.38 | 0.39 |
| 13 | 1.01 | 0.26 | 0.44 | 0.57 | 0.74 | 0.40 | 0.91 | 0.68 | 1.00 | 0.74 | 1.33 | 1.02 | 0.57 | 0.37 | 0.34 | 0.43 |
| 14 | 1.42 | 1.58 | 1.24 | 1.41 | 0.54 | 0.30 | 0.69 | 0.51 | 0.20 | 0.80 | 0.57 | 0.52 | 0.45 | 0.42 | 0.53 | 0.47 |
| 15 | 0.62 | 0.52 | 0.58 | 0.57 | 0.40 | 0.60 | 0.37 | 0.46 | 0.10 | 0.33 | 0.20 | 0.21 | 0.26 | 0.38 | 0.40 | 0.35 |
| 計 | 24.80 | 23.92 | 24.20 | 1.62 | 18.20 | 16.90 | 14.90 | 1.11 | 16,60 | 16.43 | 17.40 | 1.12 | 10.57 | 9.25 | 11.29 | 0.65 |

### A.　樹高連年生長

四樹種之樹高連年生長量列如第3表，並依據表中之生長量，進行變方分析如次：

樹高生長變方分析表　(第 4 表)

(Tab. 4)　Analysis of variance of height current annual increnent

| 變因 | 自由度 | 平方和 | 均方 | F |
|---|---|---|---|---|
| 樹株間 | 2 | 0.1156 | | |
| 樹種間 | 3 | 19.4972 | 6.4991 | 21.6637** |
| 樹齡間 | 14 | 20.6615 | 1.4758 | 4.9193** |
| 樹種×樹齡 | 42 | 15.4317 | 0.3674 | 1.2247 |
| 機差 | 118 | 35.4014 | 0.3000 | |
| 總計 | 179 | 91.1074 | | |

註：*示顯著在5%標點，即示顯著；**示顯著在1%標點，即示極顯着；以下均同此。

上表分析之結果，樹種間及樹齡間之F值均示極顯著，即示該二項之平方和差異極顯著，於是進行 t 測驗如次：

a. 樹種間

先求出四樹種樹高生長量均數之差異顯著標準值：

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{0.3000}{3 \times 15}} = 1.98 \times 0.1155 = 0.2287$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{0.3000}{3 \times 15}} = 2.62 \times 0.1155 = 0.3026$$

再行比較其生長量如下第5表：

各樹種間樹高生長比較表　　第 5 表

(Tab. 5) Comparison of the current annual increment of height among species.

| 樹　種 | 生長量 (m) | 差 | 異 | |
|---|---|---|---|---|
| 麻六甲合歡 | 1.62 | | | |
| 柚木 | 1.12 | 6.50 | | |
| 鐵刀木 | 1.11 | 0.51 | 0.01 | |
| 印度黃檀 | 0.69 | 0.93 | 0.43 | 0.42 |

註：上表差異欄內，實線以下示顯著在1%標點，即示極顯著之差；以下均同此。

四樹種之樹高生長，由表上測驗結果，麻六甲合歡之生長量與其他三樹種間之差異極大，即呈極顯著之差異，而示其生長最優，柚木與鐵刀木差異微小，即示兩樹種之樹高生長相彷彿，然柚木鐵刀木與印度黃檀，差異極顯著，即印度黃檀之生長示最劣極爲明顯。

b. 樹齡間

先求出各樹齡樹高生長量均數之差異顯著標準值：

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{0.3000}{3 \times 4}} = 1.98 \times 0.2236 = 0.4427$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{0.3000}{3 \times 4}} = 2.62 \times 0.2236 = 0.5858$$

再行比較其生長量如下第6表：

由表上測驗結果觀之，2～7 及 9 等各樹齡間差異均不顯著，即示其生長相彷彿，且爲全樹齡中生長最優時期，1,8 及 10～15等各樹齡互相間之差異不顯著，示其生長相彷彿，但與前列各年生絕不相同，示顯著或極顯著之差異，表示其生長較劣。

各樹齡間樹高生長量比較表　　第 6 表

(Tab. 6)　Comparison of the current annual increment of height among age-gradatio s.

| 樹齡(年) | 生長量(m) | 差 | | | | | | | 異 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.60 | | | | | | | | | | | | | | |
| 4 | 1.54 | 0.06 | | | | | | | | | | | | | |
| 3 | 1.50 | 0.10 | 0.04 | | | | | | | | | | | | |
| 5 | 1.36 | 0.24 | 0.18 | 0.14 | | | | | | | | | | | |
| 7 | 1.35 | 0.25 | 0.19 | 0.15 | 0.01 | | | | | | | | | | |
| 6 | 1.32 | 0.28 | 0.22 | 0.18 | 0.04 | 0.03 | | | | | | | | | |
| 9 | 1.23 | 0.37 | 0.31 | 0.27 | 0.13 | 0.12 | 0.09 | | | | | | | | |
| 10 | 1.14 | 0.46 | 0.40 | 0.36 | 0.22 | 0.21 | 0.18 | 0.09 | | | | | | | |
| 8 | 1.12 | 0.48 | 0.42 | 0.38 | 0.24 | 0.23 | 0.20 | 0.11 | 0.02 | | | | | | |
| 12 | 1.10 | 0.50 | 0.44 | 0.40 | 0.26 | 0.25 | 0.22 | 0.13 | 0.04 | 0.02 | | | | | |
| 1 | 1.09 | 0.51 | 0.45 | 0.41 | 0.27 | 0.26 | 0.23 | 0.14 | 0.05 | 0.03 | 0.01 | | | | |
| 11 | 0.93 | 0.67 | 0.61 | 0.57 | 0.43 | 0.42 | 0.39 | 0.30 | 0.21 | 0.19 | 0.17 | 0.16 | | | |
| 14 | 0.73 | 0.87 | 0.81 | 0.77 | 0.63 | 0.62 | 0.59 | 0.50 | 0.41 | 0.39 | 0.37 | 0.36 | 0.20 | | |
| 13 | 0.68 | 0.92 | 0.86 | 0.82 | 0.68 | 0.67 | 0.64 | 0.55 | 0.46 | 0.44 | 0.42 | 0.41 | 0.25 | 0.05 | |
| 15 | 0.40 | 1.20 | 1.14 | 1.10 | 0.96 | 0.95 | 0.92 | 0.83 | 0.74 | 0.72 | 0.70 | 0.69 | 0.53 | 0.33 | 0.28 |

註：上表差異欄內虛線以下，示顯著在5%標點，即示顯著；以下均同此。

B. **胸高直徑連年生長**

四樹種之胸高直徑連年生長量列如第7表，並依據表中之生長量進行變方分析如次：

胸高直徑連年生長量比較表　　單位：Cm　　第 7 表

(Tab. 7)　Current annual increment of Diamater breast high. (D.B.H)

| 樹齡年 | 麻六甲合歡 I | II | III | 平均 | 鐵刀木 I | II | III | 平均 | 柚木 I | II | III | 平均 | 印度黃檀 I | II | III | 平均 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 2.54 | 1.02 | 1.65 | 1.74 | 1.78 | 1.09 | 0.92 | 1.26 | 1.32 | 1.73 | 1.05 | 1.37 | 0.66 | 0.53 | 0.50 | 0.56 |
| 4 | 1.12 | 1.66 | 3.06 | 1.95 | 1.66 | 1.43 | 1.68 | 1.59 | 1.53 | 1.04 | 1.36 | 1.31 | 0.68 | 0.51 | 0.49 | 0.56 |
| 5 | 2.10 | 3.62 | 3.24 | 2.99 | 1.51 | 1.08 | 0.65 | 1.08 | 1.22 | 2.02 | 1.02 | 1.42 | 0.72 | 0.75 | 0.51 | 0.66 |
| 6 | 1.52 | 1.42 | 1.87 | 1.60 | 0.84 | 1.28 | 0.52 | 0.88 | 1.26 | 1.66 | 0.90 | 1.27 | 1.06 | 0.71 | 0.84 | 0.87 |
| 7 | 1.31 | 1.37 | 2.13 | 1.60 | 1.31 | 1.16 | 0.89 | 1.12 | 1.11 | 1.58 | 0.95 | 1.21 | 0.95 | 0.92 | 0.63 | 0.83 |
| 8 | 2.55 | 2.36 | 1.78 | 2.23 | 1.01 | 1.71 | 0.75 | 1.16 | 1.44 | 1.27 | 1.36 | 1.36 | 1.28 | 0.90 | 0.85 | 1.01 |
| 9 | 2.12 | 1.26 | 1.58 | 1.65 | 1.80 | 1.56 | 0.88 | 1.41 | 1.20 | 1.53 | 1.51 | 1.41 | 1.22 | 1.09 | 0.91 | 1.07 |
| 10 | 3.36 | 1.68 | 1.60 | 2.21 | 1.10 | 1.97 | 0.98 | 1.35 | 0.89 | 1.05 | 1.58 | 1.17 | 1.09 | 1.01 | 0.82 | 0.97 |
| 11 | 2.11 | 2.65 | 1.42 | 2.06 | 1.66 | 1.12 | 1.06 | 1.28 | 0.63 | 0.66 | 1.38 | 0.89 | 1.16 | 1.15 | 1.02 | 1.11 |
| 12 | 1.38 | 1.68 | 1.28 | 1.45 | 1.76 | 1.67 | 1.22 | 1.56 | 0.78 | 0.56 | 1.02 | 0.79 | 1.05 | 1.23 | 1.21 | 1.16 |
| 13 | 2.13 | 2.28 | 2.86 | 1.76 | 0.96 | 1.20 | 1.17 | 1.11 | 0.62 | 0.50 | 0.83 | 0.65 | 1.05 | 1.31 | 1.09 | 1.15 |
| 14 | 1.59 | 2.38 | 2.70 | 1.53 | 1.26 | 1.42 | 0.95 | 1.21 | 0.50 | 0.56 | 0,57 | 0.54 | 1.04 | 1.41 | 1.28 | 1.24 |
| 15 | 1.28 | 2.92 | 2.61 | 1.60 | 1.00 | 0.79 | 0.74 | 0.83 | 0.66 | 0.36 | 0.70 | 0.57 | 1.19 | 0.69 | 1.09 | 0.99 |
| 計 | 25.04 | 26.30 | 21.78 | 1.88 | 17.67 | 17.44 | 12.41 | 1.22 | 13.16 | 14.52 | 14.23 | 1.07 | 13.15 | 12.21 | 11.24 | 0,94 |

胸高直徑生長變方分析表　　第 8 表

(Tab 8)　Analysis of variance of D.B.H. current annual increment.

| 變　因 | 自由度 | 平　方　和 | 均　方 | F |
|---|---|---|---|---|
| 樹株間 | 2 | 1.3242 | | |
| 樹種間 | 3 | 20.1413 | 6.7138 | 52.8230** |
| 樹齡間 | 12 | 3.2733 | 0.2728 | 2.1463* |
| 樹種×樹齡 | 36 | 16.8829 | 0.4690 | 3.6900** |
| 機　差 | 102 | 12.9618 | 0.1271 | |
| 總　計 | 155 | 54.5835 | | |

上表分析之結果，樹種間及樹種×樹齡之 F 值均示極顯著，樹齡間之 F 值示顯著，即示前者兩項目之平方和差異均極顯著，而後者示顯著，於是可進行 t 測驗如次：

a.　樹種間

先求出四樹種胸高直徑生長量均數之差異顯著標準值；

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{0.1271}{3 \times 13}} = 1.98 \times 0.0807 = 0.1598$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{0.1271}{3 \times 13}} = 2.63 \times 0.0807 = 0.2122$$

再行比較其生長量如下第 9 表：

各樹種間胸高直徑生長量比較表　　第 9 表

(Tab. 9)　Comparison of the current annual increment of D.B H. among species.

| 樹　種 | 生長量 (Cm) | 差 | 異 | |
|---|---|---|---|---|
| 麻六甲合歡 | 1.88 | | | |
| 鐵　刀　木 | 1.22 | 0.66 | | |
| 柚　　　木 | 1.07 | 0.81 | 0.15 | |
| 印度黃檀 | 0.94 | 0.94 | 0.28 | 0.13 |

由表上測驗結果，麻六甲合歡與其他三樹種之間均示極顯著之差異，即麻六甲合歡示其生長最上，鐵刀木與柚木或柚木與印度黃檀之差異，均不顯著，示其生長相彷彿，然鐵刀木與印度黃檀，即示差異極顯著，表示鐵刀木之生長確較印度黃檀為優。

b.　樹齡間

先求出各樹齡胸高直徑生長量均數之差異顯著標準值；

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{0.1271}{3 \times 4}} = 1.98 \times 0.1670 = 0.3307$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{0.1271}{3 \times 4}} = 2.63 \times 0.1670 = 0.4392$$

再行比較其生長量如下第 10 表

各樹齡間胸高直徑生長量比較表　　第10表

(Tab. 10)　Comparison of the current annual increment of D.B.H. among age-gradations.

| 樹齡 (年) | 生長量 (cm) | 差異 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1.54 | | | | | | | | | | | | |
| 8 | 1.44 | 0.10 | | | | | | | | | | | |
| 10 | 1.43 | 0.11 | 0.01 | | | | | | | | | | |
| 9 | 1.39 | 0 15 | 0.05 | 0.04 | | | | | | | | | |
| 4 | 1.35 | 0.19 | 0.09 | 0.08 | 0.04 | | | | | | | | |
| 11 | 1.34 | 0.20 | 0.10 | 0 09 | 0.05 | 0.01 | | | | | | | |
| 12 | 1.24 | 0.30 | 0.20 | 0.19 | 0.15 | 0.11 | 0.10 | | | | | | |
| 3 | 1.23 | 0.31 | 0.21 | 0.20 | 0.16 | 0.12 | 0.11 | 0.01 | | | | | |
| 7 | 1.19 | 0.35 | 0.25 | 0.24 | 0.20 | 0.16 | 0.15 | 0.05 | 0,04 | | | | |
| 13 | 1.17 | 0.37 | 0.27 | 0.26 | 0.22 | 0.18 | 0.17 | 0.07 | 0.06 | 0.02 | | | |
| 6 | 1.16 | 0.38 | 0.28 | 0.27 | 0.23 | 0.19 | 0.18 | 0.08 | 0.07 | 0.03 | 0.01 | | |
| 14 | 1.13 | 0.41 | 0.31 | 0.30 | 0.26 | 0.22 | 0.21 | 0.11 | 0.10 | 0.06 | 0.04 | 0.03 | |
| 15 | 1.00 | 0.54 | 0.44 | 0.43 | 0.39 | 0.35 | 0.34 | 0.24 | 0.23 | 0.19 | 0.17 | 0.16 | 0.13 |

由表上測驗結果觀之，則3～5及8～12等各樹齡互相間之差異不顯著，示其生長相類似，且爲全樹齡中生長最優時期，6，7，13及14各年生互相間之差異不顯著，雖示其生長相彷彿，但與5年生者示顯著之差異，生長較劣，尤其15年生者，與5，8年生示極顯著之差異，表示15年生之生長爲最劣。

c.　樹種×樹齡

樹種×樹齡之測驗，得分(1)每樹種之各樹齡間及(2)每樹齡之各樹種間之二部份進行之。

先求出其胸高直徑生長量均數之差異標準值，然後再分別進行測驗，而比較於後：

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{0.1271}{3}} = 1.98 \times 0.2911 = 0.5764$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{0.1271}{3}} = 2.63 \times 0.2911 = 0.7656$$

再行比較其生長量如下：

(1) 每樹種各樹齡間胸高直徑生長

**i ) 麻六甲合歡**

廍六甲合歡各樹齡間胸高直徑生長量比較表　第11表

(Tab. 11)　Comparison of the current annual increment of D.B.H.
East India Walnut among age-gradations.

| 樹齡 (年) | 生長量 (cm) | 差異 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 2.99 | | | | | | | | | | | | |
| 8 | 2.23 | 0.76 | | | | | | | | | | | |
| 10 | 2.21 | 0.78 | 0.02 | | | | | | | | | | |
| 11 | 2.06 | 0.93 | 0.17 | 0.15 | | | | | | | | | |
| 4 | 1.59 | 1.04 | 0.28 | 0.26 | 0.11 | | | | | | | | |
| 13 | 1.76 | 1.23 | 0.47 | 0.45 | 0.30 | 0.19 | | | | | | | |
| 3 | 1.74 | 1.25 | 0.49 | 0.47 | 0.32 | 0.21 | 0.02 | | | | | | |
| 9 | 1.65 | 1.34 | 0.58 | 0.56 | 0.41 | 0.30 | 0.11 | 0.09 | | | | | |
| 6 | 1.60 | 1.39 | 0.63 | 0.61 | 0.46 | 0.35 | 0.16 | 0.14 | 0.05 | | | | |
| 7 | 1.60 | 1.39 | 0.63 | 0.61 | 0.46 | 0.35 | 0.16 | 0.14 | 0.05 | 0.00 | | | |
| 15 | 1.60 | 1.36 | 0.63 | 0.61 | 0.46 | 0.35 | 0.16 | 0.14 | 0.05 | 0.00 | 0.00 | | |
| 14 | 1.53 | 1.46 | 0.70 | 0.68 | 0.53 | 0.42 | 0.23 | 0.21 | 0.12 | 0.07 | 0.07 | 0.07 | |
| 12 | 1.45 | 1.54 | 0.78 | 0.76 | 0.61 | 0.50 | 0.31 | 0.29 | 0.20 | 0.15 | 0.15 | 0.15 | 0.08 |

由表上測驗結果觀之，5，8及10等各樹齡之生長爲全樹齡中最優時期，與其他樹齡間示極顯著或顯著之差異，餘各樹齡互相間之差異不顯著，示其生長相彷彿，但較前列各樹齡確有不同，於12年生之生長示最劣時期。

ii）鐵 刀 木

鐵刀木各樹齡間胸高直徑生長量比較表　第12表

(Tab. 12)　Comparison of the current annual increment of D.B.H.
Siamese Senna among age-gradations.

| 樹齡 (年) | 生長量 (cm) | 差異 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 1.59 | | | | | | | | | | | | |
| 12 | 1.56 | 0.03 | | | | | | | | | | | |
| 9 | 1.41 | 0.18 | 0.15 | | | | | | | | | | |
| 10 | 1.35 | 0.24 | 0.21 | 0.06 | | | | | | | | | |
| 11 | 1.28 | 0.31 | 0.28 | 0.13 | 0.07 | | | | | | | | |
| 3 | 1.26 | 0.33 | 0.30 | 0.15 | 0.09 | 0.02 | | | | | | | |
| 14 | 1.21 | 0.38 | 0.35 | 0.20 | 0.14 | 0.07 | 0.05 | | | | | | |
| 8 | 1.16 | 0.43 | 0.40 | 0.25 | 0.19 | 0.12 | 0.10 | 0.05 | | | | | |
| 7 | 1.12 | 0.47 | 0.44 | 0.29 | 0.23 | 0.16 | 0.14 | 0.09 | 0.04 | | | | |
| 13 | 1.11 | 0.48 | 0.45 | 0.30 | 0.24 | 0.17 | 0.15 | 0.10 | 0.05 | 0.01 | | | |
| 5 | 1.08 | 0.51 | 0.48 | 0.33 | 0.27 | 0.20 | 0.18 | 0.13 | 0.08 | 0.04 | 0.03 | | |
| 6 | 0.88 | 0.71 | 0.68 | 0.53 | 0.47 | 0.40 | 0.38 | 0.33 | 0.28 | 0.24 | 0.23 | 0.20 | |
| 16 | 0.83 | 0.76 | 0.73 | 0.58 | 1.52 | 0.45 | 0.43 | 0.38 | 0.33 | 0.29 | 0.28 | 0.25 | 0.05 |

由表上測驗結果觀之，除6，15兩樹齡示差異顯著外，其餘各樹齡互相間之差異均不顯著，示其生長相彷彿,然而6，15兩年生之生長較劣。

iii) 柚　木

柚木各樹齡間胸高直徑生長量比較表　第13表

(Tab. 13)　Comparison of the current annual increment of D.B.H. Teak among age-gradations.

| 樹齡 (年) | 生長量 (cm) | 差 | | | | | | | | | | | 異 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1.42 | | | | | | | | | | | | |
| 9 | 1.41 | 0.01 | | | | | | | | | | | |
| 3 | 1.37 | 0.05 | 0.04 | | | | | | | | | | |
| 8 | 1.36 | 0.06 | 0.05 | 0.01 | | | | | | | | | |
| 4 | 1.31 | 0.11 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 6 | 1.27 | 0.15 | 0.14 | 0.10 | 0.09 | 0.04 | | | | | | | |
| 7 | 1.21 | 0.21 | 0.20 | 0.16 | 0.15 | 0.10 | 0.06 | | | | | | |
| 10 | 1.17 | 0.25 | 0.24 | 0.20 | 0.19 | 0.14 | 0.10 | 0.04 | | | | | |
| 11 | 0.89 | 0.53 | 0.52 | 0.48 | 0.47 | 0.42 | 0.38 | 0.32 | 0.28 | | | | |
| 12 | 0.79 | 0.63 | 0.62 | 0.58 | 0.57 | 0.52 | 0.48 | 0.42 | 0.38 | 0.10 | | | |
| 13 | 0.65 | 0.77 | 0.76 | 0.72 | 0.71 | 0.66 | 0.62 | 0.56 | 0.52 | 0.24 | 0.14 | | |
| 15 | 0.57 | 0.85 | 0.84 | 0.80 | 0.79 | 0.74 | 0.70 | 0.64 | 0.60 | 0.32 | 0.22 | 0.08 | |
| 14 | 0.54 | 0.88 | 0.87 | 0.83 | 0.82 | 0.77 | 0.73 | 0.67 | 0.63 | 0.35 | 0.25 | 0.11 | 0.03 |

由表上之檢定結果觀之，柚木之胸高直徑生長量以3～11等各樹齡間之生長爲最優，且互相間之差異不顯著，即示其生長相彷彿，但12～15等各樹齡與上列各樹齡比較，即示顯著或極顯著之差異，爲全樹齡中生長最劣時期。

iv) 印度黃檀

印度黃檀各樹齡間胸高直徑生長量比較表　第14表

(Tab. 14)　Comparison of the current annual increment of D.B.H. Sissoo among age-gradations.

| 樹齡 (年) | 生長量 (cm) | 差 | | | | | | | | | | | 異 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 1.24 | | | | | | | | | | | | |
| 12 | 1.16 | 0.08 | | | | | | | | | | | |
| 13 | 1.15 | 0.09 | 0.01 | | | | | | | | | | |
| 11 | 1.11 | 0.13 | 0.05 | 0.04 | | | | | | | | | |
| 9 | 1.07 | 0.17 | 0.09 | 0.08 | 0.04 | | | | | | | | |
| 8 | 1.01 | 0.23 | 0.15 | 0.14 | 0.10 | 0.06 | | | | | | | |
| 15 | 0.99 | 0.25 | 0.17 | 0.16 | 0.12 | 0.08 | 0.02 | | | | | | |
| 10 | 0.97 | 0.27 | 0.19 | 0.18 | 0.14 | 0.10 | 0.04 | 0.02 | | | | | |
| 6 | 0.87 | 0.37 | 0.29 | 0.28 | 0.24 | 0.20 | 0.14 | 0.12 | 0.10 | | | | |
| 7 | 0.83 | 0.41 | 0.33 | 0.32 | 0.28 | 0.24 | 0.18 | 0.16 | 0.14 | 0.04 | | | |
| 5 | 0.66 | 0.58 | 0.50 | 0.49 | 0.45 | 0.41 | 0.35 | 0.33 | 0.31 | 0.21 | 0.17 | | |
| 3 | 0.56 | 0.68 | 0.60 | 0.59 | 0.55 | 0.51 | 0.45 | 0.43 | 0.41 | 0.31 | 0.27 | 0.10 | |
| 4 | 0.56 | 0.68 | 0.60 | 0.59 | 0.55 | 0.51 | 0.45 | 0.43 | 0.41 | 0.31 | 0.27 | 0.10 | 0.00 |

由表上之檢定結果觀之，在7～10及15等樹齡間之差異均示不顯著，其生長相彷彿，但與11～14等樹齡間示顯著之差異，即由此可知在幼年時之生長較劣，而與柚木者似相反之趨勢。

(2) 每樹齡各樹種間胸高直徑生長

每樹齡之各樹種胸高直徑生長量比較如第15表：

每樹齡各樹種間胸高直徑生長量比較表　第15表

(Tab. 15)　Comparison of the current annual increment of D.B.H among species on each age-gradations.

| 樹齡年 | 生長量 (cm) | | | | 差異 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 麻六甲合歡 (1) | 鐵刀木 (2) | 柚木 (3) | 印度黃檀 (4) | (1)-(2) | (1)-(3) | (1)-(4) | (2)-(3) | (2)-(4) | (3)-(4) |
| 3 | 1.74 | 1.26 | 1.37 | 0.56 | 0.48 | 0.37 | 1.19** | 0.89** | 0.70* | 0.81** |
| 4 | 1.95 | 1.59 | 1.31 | 0.56 | 0.36 | 0.64** | 1.39** | 0.28 | 1.03** | 0.75** |
| 5 | 2.99 | 1.08 | 1.42 | 0.66 | 1.91** | 1.57** | 2.33** | -0.51 | 0.42 | 0.76* |
| 6 | 1.60 | 0.88 | 1.27 | 0.87 | 0.72* | 0.33 | 0.73* | -0.39 | 0.01 | 0.40 |
| 7 | 1.66 | 1.12 | 1.21 | 0.93 | 0.48 | 0.39 | 0.77** | -0.09 | 0.29 | 0.33 |
| 8 | 2.23 | 1.16 | 1.36 | 1.01 | 1.07** | 0.87** | 1.22** | -0.20 | 0.15 | 0.35 |
| 9 | 1.65 | 1.41 | 1.41 | 1.07 | 0.24 | 0.24 | 0.53* | 0 | 0.34 | 0.34 |
| 10 | 2.21 | 1.35 | 1.17 | 0.97 | 0.86** | 1.04** | 1.24** | 0.18 | 0.38 | 0.20 |
| 11 | 2.06 | 1.28 | 0.89 | 1.11 | 0.76** | 1.17** | 0.95** | 0.39 | 0.17 | -0.22 |
| 12 | 1.45 | 1.56 | 0.79 | 1.16 | -0.11 | 0.66** | 0.29 | 0.77** | 0.40 | -0.37 |
| 13 | 1.76 | 1.11 | 0.65 | 1.15 | 0.65** | 1.11** | 0.61* | 0.46 | -0.04 | -0.50 |
| 14 | 1.53 | 1.21 | 0.54 | 1.24 | 0.32 | 0.99** | 0.29 | 0.67** | -0.03 | -0.70* |
| 15 | 1.60 | 0.83 | 0.57 | 0.99 | 0.77** | 1.03** | 0.61* | 0.26 | -0.16 | -0.42 |

由表上測驗結果觀察之，(i) 麻六甲合歡與鐵刀木，於12年生時示負符號，3，4，7，9，12，14等各樹齡均示正符號差異不顯著外，餘各樹齡均示正符號之顯著或極顯著之差異，可知麻六甲合歡之生長量確較大爲鐵刀木；與柚木者，除3，6，7，9，等樹齡外，餘均示正符號之顯著或極顯著之差異；又與印度黃檀比較，亦均呈正符號之顯著或極顯著之差異，故可知麻六甲合歡之生長的確在各樹齡間均凌駕其他三樹種，而生長示最優。(ii) 鐵刀木與柚木，除3，12，14等三樹齡示正符號之顯著或極顯著之差異外，餘均示不顯著，雖5至9樹齡間示有負符號，但各樹齡間之生長相彷彿；又與印度黃檀比較，除3，4兩樹齡示顯著或極顯著之差異外，餘均呈差異不顯著，即示其生長相類似。(iii)柚木與印度黃檀，在幼年時柚木之生長確較爲優，除3年生示極顯著，4，5年生示顯著之差異外，餘雖11～15年生間均呈有負符號，但其差異不顯著，即示在壯年時印度黃檀之生長，較優爲柚木之生長。

c.　胸高斷面積連年生長

四樹種之胸高斷面積連年生長量，列如第16表，並依據表中四樹種之胸高斷面積生長量，進行變方分析如次：

胸高斷面積連年生長量表　　單位：m²　　第16表

(Tab. 16)　Current annual increment of Basal area.

| 樹齡(年) | 麻六甲合歡 | | | | 鐵刀木 | | | | 柚木 | | | | 印度黃檀 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | 平均 | I | II | III | 平均 | I | II | III | 平均 | I | II | III | 平均 |
| 3 | 12.01 | 3.54 | 14.37 | 9.97 | 2.49 | 3.64 | 2.87 | 3.00 | 4.35 | 11.10 | 3.09 | 6.18 | 1.27 | 0.79 | 0.75 | 0.94 |
| 4 | 8.51 | 9.26 | 37.97 | 18.58 | 6.80 | 7.60 | 8.65 | 7.68 | 8.48 | 8.94 | 6.58 | 8.00 | 2.03 | 1.17 | 1.11 | 1.13 |
| 5 | 21.28 | 35.20 | 56.24 | 37.57 | 9.95 | 7.87 | 5.30 | 7.71 | 9.38 | 22.21 | 6.85 | 12.21 | 2.92 | 2.47 | 1.56 | 2.32 |
| 6 | 19.72 | 19.12 | 39.96 | 26.37 | 7.09 | 7.30 | 4.19 | 7.53 | 12.16 | 23.05 | 7.39 | 14.20 | 5.80 | 3.15 | 3.46 | 4.14 |
| 7 | 19.91 | 21.75 | 52.21 | 31.29 | 13.26 | 12.76 | 8.15 | 11.39 | 12.77 | 25.96 | 9.18 | 15.97 | 6.69 | 5.26 | 3.32 | 5.09 |
| 8 | 46.48 | 44.37 | 49.10 | 46.65 | 12.07 | 22.66 | 7.85 | 14.18 | 19.45 | 23.71 | 15.62 | 19.93 | 11.26 | 6.44 | 5.47 | 7.72 |
| 9 | 46.43 | 27.28 | 47.75 | 60.21 | 25.47 | 24.67 | 10.32 | 20.15 | 18.70 | 31.93 | 20.74 | 23.79 | 13.13 | 9.49 | 7.11 | 9.91 |
| 10 | 88.03 | 40.24 | 52.36 | 62.22 | 18.08 | 36.62 | 12.93 | 22.54 | 15.33 | 24.04 | 25.54 | 21.64 | 13.70 | 10.46 | 7.52 | 10.56 |
| 11 | 64.35 | 72.49 | 49.83 | 48.39 | 30.87 | 23.54 | 15.69 | 23.37 | 11.60 | 16.07 | 25.51 | 17.73 | 16.64 | 13.84 | 10.33 | 13.77 |
| 12 | 45.87 | 51.67 | 47.63 | 62.45 | 37.91 | 38.84 | 20.23 | 32.33 | 15.23 | 14.04 | 20.79 | 16.69 | 16.88 | 17.12 | 11.97 | 16.32 |
| 13 | 76.67 | 77.22 | 33.45 | 52.82 | 22.37 | 31.53 | 21.61 | 25.17 | 12.79 | 13.10 | 18.11 | 14.67 | 18.61 | 20.86 | 15.45 | 23.31 |
| 14 | 59.07 | 89.31 | 28.08 | 58.82 | 31.89 | 39.28 | 19.12 | 30.10 | 10.75 | 15.05 | 13.07 | 12.96 | 20.15 | 25.46 | 20.53 | 22.05 |
| 15 | 52.55 | 120.73 | 25.10 | 66.46 | 26.85 | 21.97 | 15.88 | 21.52 | 14.80 | 9.80 | 16.82 | 13.81 | 25.13 | 13.60 | 19.51 | 19.41 |
| 計 | 560.88 | 613.48 | 534.05 | 43.81 | 245.10 | 282.23 | 152.79 | 17.44 | 165.79 | 239.00 | 189.29 | 15.23 | 154.20 | 130.11 | 111.59 | 10.15 |

註：表中生長量，係將原數值×10,000，以下均此。

胸高斷面積生長變方分析表 第17表

(Tab. 17) Analysis of variance of Basal area current annual increment.

| 變因 | 自由度 | 平方和 | 均方 | F |
|---|---|---|---|---|
| 樹株間 | 2 | 738.5721 | | |
| 樹種間 | 3 | 26597.3627 | 81865.7876 | 68.4987** |
| 樹齡間 | 12 | 15118.4017 | 1259.8668 | 9.7339** |
| 樹種×樹齡 | 36 | 2947.5129 | 81 8754 | 0.6325 |
| 機差 | 102 | 13201.7755 | 129.4300 | |
| 總計 | 155 | 58603.6249 | | |

表上分析結果，樹種間及樹齡間之F值均示極顯著；即示該兩項目之平方和差異極顯著，於是可進行 t 測驗如次；

a. 樹種間

先求出四樹種之胸高斷面積生長量均數之差異顯著標準值：

$$D_1 = t_{5\%} \times \sqrt{2\times\frac{129.4300}{3\times 13}} = 1.98 \times 2.5763 = 5.1011$$

$$D_2 = t_{1\%} \times \sqrt{2\times\frac{129.4300}{3\times 13}} = 2.63 \times 2.5763 = 6.7757$$

再行比較其生長量如下第18表：

各樹種間胸高斷面積生長量比較表 第18表

(Tab. 18) Comparison of the current annual increment of Basal area among species.

| 樹種 | 生長量 ($m^2$) | 差異 | | |
|---|---|---|---|---|
| 麻六甲合歡 | 43.81 | | | |
| 鐵刀木 | 17.44 | 26.37 | | |
| 柚木 | 15.23 | 28.58 | 2.21 | |
| 印度黃檀 | 10.15 | 33.66 | 7.29 | 5.08 |

由表上測驗結果，麻六甲合歡與其他三樹種之差異均呈極顯著，即示麻六甲合歡之生長確最優，鐵刀木將次之，與印度黃檀示極顯著之差異，但與柚木之生長差異並無顯著，示生長相彷彿，印度黃檀之生長最劣。

b. 樹齡間

先求出各樹齡胸高斷面積生長量均數之差異顯著標準值：

$$D_1 = t_{5\%} \times \sqrt{2\times\frac{129.430}{3\times 4}} = 1.98 \times 4.6445 = 9.1961$$

$$D_2 = t_{1\%} \times \sqrt{2\times\frac{129.430}{3\times 4}} = 2.63 \times 4.6445 = 12.2150$$

再行比較其生長量如第19表：

各樹齡間胸高斷面積生長量比較表　　第19表

(Tab. 19)　Comparison of the current annual icrenment of Basal area among age-gradations.

| 樹齡 (年) | 生長量 (m²) | 差 | | | | | | | | | | | 異 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 33.10 | | | | | | | | | | | | |
| 14 | 30.98 | 2.10 | | | | | | | | | | | |
| 15 | 30.41 | 2.69 | 0.57 | | | | | | | | | | |
| 11 | 29.27 | 3.83 | 1.71 | 1.14 | | | | | | | | | |
| 10 | 28.74 | 4.36 | 2.24 | 1.67 | 0.53 | | | | | | | | |
| 12 | 28.43 | 4.67 | 2.55 | 1.98 | 0.84 | 0.31 | | | | | | | |
| 9 | 23.59 | 9.51 | 7.39 | 6.82 | 5.68 | 5.15 | 4.84 | | | | | | |
| 8 | 22.12 | 10.98 | 8.86 | 8.29 | 7.15 | 6.62 | 6.39 | 1.47 | | | | | |
| 7 | 15.94 | 13.56 | 15.04 | 14.47 | 13.33 | 12.80 | 12.49 | 7.67 | 6.18 | | | | |
| 5 | 15.10 | 18.00 | 15.88 | 15.31 | 14.17 | 13.64 | 13.33 | 8.49 | 7.02 | 0.84 | | | |
| 6 | 13.06 | 20.04 | 17.92 | 17.35 | 16.21 | 15.68 | 15.37 | 10.53 | 9.06 | 2.88 | 2.04 | | |
| 4 | 8.92 | 24.18 | 22.06 | 21.49 | 20.35 | 19.82 | 19.51 | 14.67 | 13.20 | 7.02 | 6.18 | 4.14 | |
| 3 | 5.02 | 28.08 | 25.96 | 25.39 | 24.25 | 23.72 | 23.41 | 18.57 | 17.10 | 10.92 | 10.08 | 8.04 | 3.90 |

由表上測驗結果觀之，10至15等樹齡間之差異均呈不顯著，示其生長相彷彿，且爲全樹齡中生長最優期時，3至7等各樹齡間之差異，亦均呈不顯著，示其生長相彷彿，但與前列各樹齡間之差異，示顯著或極顯著，即表示其生長爲全樹齡中生長最劣時期。

D.　材積連年生長

四樹種之材積連年生長量，列如第20表，並依據表中之材積連年生長量進行變方分析如次：

材積連年生長量表　　單位$m^3$　　第20表

(Tab. 20)　Current annual increment of Valume.

| 樹齡(年) | 麻六甲合歡 | | | | 鐵刀木 | | | | 柚木 | | | | 印度黃檀 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | 平均 | I | II | III | 平均 | I | II | III | 平均 | I | II | III | 均平 |
| 2 | 0.23 | 0.45 | 4.78 | 1.82 | 0.15 | 0.49 | 0.39 | 0.34 | 0.42 | 1.91 | 0.41 | 0.91 | 0.16 | 0.12 | 0.09 | 0.12 |
| 3 | 4.32 | 1.80 | 7.81 | 4.64 | 1.01 | 1.09 | 0.77 | 0.96 | 1.41 | 2.98 | 1.11 | 1.83 | 0.34 | 0.18 | 0.21 | 0.24 |
| 4 | 7.18 | 4.68 | 24.25 | 12.04 | 1.74 | 2.46 | 2.71 | 2.30 | 3.07 | 3.18 | 2.50 | 2.90 | 0.69 | 0.54 | 0.32 | 0.52 |
| 5 | 12.98 | 22.59 | 37.48 | 24.35 | 2.98 | 3.61 | 2.66 | 3.08 | 4.07 | 9.04 | 2.83 | 5.31 | 0.86 | 0.91 | 0.52 | 0.76 |
| 6 | 12.88 | 10.48 | 37.37 | 20.24 | 4.04 | 9.20 | 3.65 | 5.63 | 5.72 | 12.00 | 3.57 | 7.10 | 1.74 | 1.28 | 1.13 | 1.38 |
| 7 | 21.62 | 17.25 | 49.11 | 29.33 | 7.62 | 12.97 | 2.59 | 7.73 | 8.07 | 14.74 | 4.85 | 9.22 | 2.43 | 2.03 | 1.41 | 1.96 |
| 8 | 30.40 | 46.49 | 45.62 | 40.84 | 10.87 | 18.36 | 7.71 | 12.31 | 12.55 | 15.17 | 11.01 | 12.91 | 3.90 | 2.70 | 2.36 | 2.99 |
| 9 | 47.58 | 33.51 | 54.91 | 45.33 | 15.28 | 31.05 | 7.11 | 17.81 | 15.48 | 19.47 | 13.88 | 16.28 | 4.52 | 3.49 | 3.49 | 3.83 |
| 10 | 84.63 | 39.27 | 62.60 | 62.17 | 14.78 | 15.10 | 9.12 | 13.00 | 15.54 | 16.30 | 18.50 | 16.78 | 4.84 | 4.02 | 4.14 | 4.33 |
| 11 | 97.10 | 76.17 | 72.66 | 81.94 | 21.53 | 22.12 | 13.62 | 19.09 | 12.27 | 13.19 | 19.89 | 15.12 | 6.88 | 5.98 | 6.67 | 6.51 |
| 12 | 87.48 | 65.08 | 73.13 | 75.23 | 29.64 | 22.25 | 15.62 | 22.50 | 16.24 | 14.02 | 16.98 | 15.75 | 7.53 | 7.82 | 8.06 | 7.80 |
| 13 | 106.41 | 80.07 | 65.61 | 84.03 | 21.46 | 31.78 | 16.64 | 23.39 | 15.51 | 12.77 | 13.82 | 14.03 | 8.74 | 9.18 | 10.16 | 9.36 |
| 14 | 129.15 | 110.86 | 59.83 | 99.95 | 29.00 | 31.07 | 19.00 | 26.38 | 15.13 | 12.30 | 12.46 | 13.03 | 10.19 | 10.44 | 11.64 | 10.76 |
| 15 | 101.31 | 151.93 | 61.59 | 104.94 | 27.00 | 27.79 | 15.98 | 23.59 | 20.48 | 11.45 | 21.23 | 17.82 | 12.53 | 8.82 | 12.76 | 11.40 |
| 計 | 743.27 | 660.63 | 656.75 | 48.35 | 187.10 | 229.34 | 117.88 | 12.72 | 146.26 | 158.52 | 143.04 | 10.66 | 65.41 | 57.51 | 62.99 | 4.43 |

註：　表中生長量，係原數值×1,000，以下均同此。

材積生長變方分析表　　第21表

(Tab. 21) Analysis of variance of Volume current annual increment.

| 變　因 | 自由度 | 平 方 和 | 均　方 | F |
|---|---|---|---|---|
| 樹 株 間 | 2 | 256.2649 | | |
| 樹 種 間 | 3 | 49065.6126 | 16355.2035 | 148.8362** |
| 樹 齡 間 | 13 | 28131.3503 | 2163.9500 | 19.6924** |
| 樹種×樹齡 | 39 | 28817.7299 | 738.9162 | 6.7243** |
| 機　差 | 110 | 12087.6077 | 109.8873 | |
| 總　計 | 167 | 118358.5634 | | |

表上分析結果，樹種間，樹齡間及樹種×樹齡之 F 值均示極顯著，即該三項之平方和差異均極顯著，於是可進行 t 測驗如次；

a. 樹種間

先求出四樹種材積生長量均數之差異顯著標準值：

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{109.8873}{3 \times 14}} = 1.98 \times 2.2800 = 4.5144$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{109.8873}{3 \times 14}} = 2.63 \times 2.2800 = 5.9964$$

再行比較其生長量如下第22表

各樹種間材積生長量比較表　　第22表

(Tab. 22) Comparison ot the current annual increment of Volume among species.

| 樹　種 | 生長量 $(m^3)$ | 差 | 異 | |
|---|---|---|---|---|
| 麻六甲合歡 | 48.35 | | | |
| 鐵 刀 木 | 12.72 | 35.63 | | |
| 柚　木 | 10.66 | 37.66 | 2.06 | |
| 印度黃檀 | 4.43 | 43.92 | 8.29 | 6.23 |

由表上測驗結果觀之，麻六甲合歡與其他樹種，均呈極顯著之差異，確與他樹種不同，而爲生長最優者，鐵刀木與柚木示相彷彿，但與印度黃檀呈極顯著之差異，可知印度黃檀之生長爲最劣。

b. 樹齡間

先求出各樹齡材積生長量均數之差異標準值：

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{109.8873}{3 \times 4}} = 1.98 \times 4.279 = 8.4724$$

$$D^2 = t_{1\%} \times \sqrt{2 \times \frac{109.8873}{3 \times 4}} = 2.63 \times 4.279 = 11.2538$$

再行比較其生長量如第23表：

各樹齡間材積生長量比較表 第23表

(Tab. 23) Comparison of the current annual increment of Volume among age-gradations.

| 樹齡 | 生長量 | 差異 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (年) | ($m^3$) | | | | | | | | | | | | | |
| 15 | 39.44 | | | | | | | | | | | | | |
| 14 | 37.60 | 1.84 | | | | | | | | | | | | |
| 13 | 32.70 | 6.74 | 4.90 | | | | | | | | | | | |
| 12 | 30.67 | 8.77 | 6.93 | 2.03 | | | | | | | | | | |
| 11 | 30.32 | 9.12 | 7.28 | 2.38 | 0.35 | | | | | | | | | |
| 10 | 22.57 | 16.87 | 15.03 | 10.13 | 8.10 | 7.75 | | | | | | | | |
| 9 | 20.81 | 18.63 | 16.79 | 11.89 | 9.86 | 9.51 | 1.76 | | | | | | | |
| 8 | 17.26 | 22.18 | 20.34 | 15.44 | 13.41 | 13.06 | 5.31 | 3.55 | | | | | | |
| 7 | 12.06 | 27.38 | 25.54 | 20.64 | 18.61 | 18.26 | 10.51 | 8.75 | 5.20 | | | | | |
| 6 | 8.59 | 39.85 | 29.01 | 24.11 | 22.08 | 21.73 | 13.98 | 12.22 | 8.67 | 3.47 | | | | |
| 5 | 8.38 | 31.06 | 29.22 | 24.32 | 22 29 | 21.97 | 14.19 | 12.49 | 8.88 | 3.68 | 0.21 | | | |
| 4 | 4.45 | 34.99 | 33.15 | 28.25 | 26.22 | 25.87 | 18.12 | 16.36 | 12.81 | 7.61 | 4.14 | 3.93 | | |
| 3 | 1.87 | 37.57 | 35.73 | 30.83 | 28.80 | 28.45 | 20.70 | 18.94 | 15.39 | 10.19 | 6.72 | 6.51 | 2.58 | |
| 2 | 0.80 | 38.64 | 36.80 | 31.90 | 29.87 | 29.52 | 21.77 | 20.01 | 16.46 | 11.26 | 7.79 | 7.58 | 3.65 | 1.07 |

由表上測驗結果，13～15等各樹齡間差異均不顯著，示其生長相彷彿，且爲全樹齡中生長最優時期，11，12年生雖較前列各年生之生長示顯著之差異，但其生長次爲前列各年生，2至10等各樹齡互相間之生長大致相同，但與前列者之差異均呈極顯著或顯著，即示其生長不如前列各年生之生長量，確較爲小。

c. 樹種×樹齡

樹種×樹齡之測驗，得分 (1) 每樹種之各樹齡間及 (2) 每樹齡之各樹種間二部分進行之。先求出其材積生長量均數之差異標準值，然後再分別進行測驗而比較之。

$$D_1 = t_{5\%} \times \sqrt{2 \times \frac{109.8873}{3}} = 1.98 \times 8.56 = 16.9484$$

$$D_2 = t_{1\%} \times \sqrt{2 \times \frac{109.8873}{3}} = 2.63 \times 8.56 = 22.5128$$

(1) 每樹種之各樹齡間材積生長

i) 麻六甲合歡

麻六甲合歡各樹齡間材積生長量比較表　第24表

(Tab. 24) Comparison of the current annual increment of volume East India Walnut among age-gradations.

| 樹齡 (年) | 生長量 ($m^3$) | 差 | | | | | | | | | | | | | 異 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 104.94 | | | | | | | | | | | | | | |
| 14 | 99.95 | 4.99 | | | | | | | | | | | | | |
| 13 | 84.03 | 20.91 | 15.92 | | | | | | | | | | | | |
| 11 | 81.94 | 23.00 | 18.01 | 2.09 | | | | | | | | | | | |
| 12 | 75.23 | 29.71 | 24.72 | 8.80 | 6.71 | | | | | | | | | | |
| 10 | 62.17 | 42.77 | 37.78 | 21.86 | 19.77 | 13.06 | | | | | | | | | |
| 9 | 45.32 | 59.62 | 54.63 | 38.71 | 36.62 | 29.91 | 16.85 | | | | | | | | |
| 8 | 40.84 | 64.10 | 59.11 | 43.19 | 41.10 | 34.39 | 21.33 | 4.48 | | | | | | | |
| 7 | 29.33 | 75.61 | 70.62 | 54.70 | 52.61 | 45.90 | 32.84 | 15.99 | 11.51 | | | | | | |
| 5 | 24.35 | 80.59 | 75.60 | 59.68 | 57.59 | 50.88 | 37.82 | 20.97 | 16.49 | 4.98 | | | | | |
| 6 | 20.24 | 84.70 | 79.71 | 63.79 | 61.70 | 54.99 | 41.93 | 25.08 | 20.00 | 9.09 | 4.11 | | | | |
| 4 | 12.04 | 92.90 | 87.91 | 71.99 | 69.90 | 63.19 | 50.13 | 33.28 | 28.80 | 17.29 | 12.31 | 8.20 | | | |
| 3 | 4.64 | 100.30 | 95.31 | 79.39 | 77.30 | 70.59 | 5753 | 40.68 | 36.20 | 24.69 | 19.71 | 15.60 | 7.40 | | |
| 2 | 1.82 | 103.12 | 98.13 | 82.21 | 80.12 | 73.41 | 60.35 | 43.50 | 39.02 | 27.51 | 22.53 | 18.42 | 10.22 | 2.82 | |

由上測驗結果觀之，14, 15 兩樹齡之生長最優，13 樹齡之生長，雖不如前者，但將次之，10～12等樹齡互相間之差異不顯著，但與前列者呈爲顯著或極顯著之差異，2～9等樹齡與前列者示極顯著之差異，其生長確較前者爲小，由此可知麻六甲合歡之年數愈多之材積生長，確較幼年時之生長爲佳。

ii)　刀木

鐵刀木各樹齡材積生長量比較表　第25表

(Tab. 25) Comparison of the current annual increment of Valume Siamese Senna among age-gradations.

| 樹齡 | 生長量 | 差 | | | | | | | | | | | | 異 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (年) | ($m^3$) | | | | | | | | | | | | | |
| 14 | 26.38 | | | | | | | | | | | | | |
| 15 | 23.59 | 2.79 | | | | | | | | | | | | |
| 13 | 23.39 | 2.99 | 0.20 | | | | | | | | | | | |
| 12 | 22.50 | 3.88 | 1.09 | 0.89 | | | | | | | | | | |
| 11 | 19.09 | 7.29 | 4.50 | 4.30 | 3.41 | | | | | | | | | |
| 9 | 17.81 | 8.57 | 5.78 | 5.58 | 4.69 | 1.28 | | | | | | | | |
| 10 | 13.00 | 13.38 | 10.59 | 10.39 | 9.50 | 6.09 | 4.81 | | | | | | | |
| 8 | 12.31 | 14.07 | 11.28 | 11.08 | 10.19 | 6.78 | 5.50 | 0.69 | | | | | | |
| 7 | 7.73 | 18.65 | 15.86 | 15.66 | 14.77 | 11.36 | 10.08 | 5.27 | 4.58 | | | | | |
| 6 | 5.63 | 20.75 | 17.96 | 17.76 | 16.87 | 13.46 | 12.18 | 7.37 | 6.68 | 2.10 | | | | |
| 5 | 3.08 | 23.30 | 20.51 | 20.31 | 19.42 | 16.01 | 14.73 | 9.92 | 9.23 | 4.65 | 2.55 | | | |
| 4 | 2.30 | 24.28 | 21.29 | 21.09 | 20.20 | 16.79 | 15.51 | 10.70 | 10.01 | 5.43 | 3.33 | 0.78 | | |
| 3 | 0.96 | 25.42 | 22.63 | 22.43 | 21.54 | 18.13 | 16.85 | 12.04 | 11.35 | 6.77 | 4.67 | 2.12 | 1.34 | |
| 2 | 0.34 | 26.04 | 23.25 | 23.05 | 22.16 | 18.75 | 17.47 | 12.66 | 11.97 | 7.39 | 5.29 | 2.74 | 2.30 | 0.62 |

由表上測驗結果觀之，8～15 等樹齡之生長最優，且互相間差異不顯著，示其生長相彷彿；6, 7 年生之生長將次之，與前列各樹齡間之生長示顯著或極顯著之差異，又2～5年生之各樹齡間之生長雖相彷彿，但與前列各年之生長，確較爲劣，示爲全樹齡中生長最劣時期。

iii)　柚　木

柚木之各樹齡間材積生長均無顯著之差異，示其生長開始至15年生間之柚木材積生長，在各樹齡間均相彷彿，大致相同。

iv)　印度黃檀

印度黃檀之各樹齡間之材積生長均無顯著之差異，即至15年生間之各年生長量大致相同，但幼年之生長較稍小11～15年生之生長量。

(2) 各樹齡之各樹種間材積生長

每樹齡之各樹種間材積生長量列如第26表：

各樹齡之各樹種材積生長量比較表　第26表

(Tab. 26) Comparison of the current annual increment of Volume among species on each age-gradations.

| 樹齡(年) | 生長量 ($m^3 \times 1000$) | | | | 差異 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 麻六甲合歡 (1) | 鐵刀木 (2) | 柚木 (3) | 印度黃檀 (4) | (1)—(2) | (1)—(3) | (1)—(4) | (2)—(3) | (2)—(4) | (3)—(4) |
| 2 | 1.82 | 0.34 | 0.91 | 0.12 | 1.48 | 0.91 | 1.70 | —0.57 | 0.22 | 0.79 |
| 3 | 4.64 | 0.96 | 1.83 | 0.24 | 3.68 | 2.81 | 4.40 | —0.87 | 0.72 | 1.59 |
| 4 | 12.04 | 2.30 | 2.92 | 0.52 | 9.73 | 9.12 | 11.52 | —0.62 | 1.78 | 2.40 |
| 5 | 24.35 | 3.08 | 5.31 | 0.76 | 21.27* | 19.04* | 23.59* | —2.23 | 2.32 | 4.55 |
| 6 | 20.24 | 5.63 | 7.10 | 1.38 | 14.61 | 14.14 | 18.86* | —1.47 | 4.25 | 5.72 |
| 7 | 29.33 | 7.73 | 9.22 | 1.96 | 21.60* | 20.1[illegible]* | 27.37** | —1.49 | 5.77 | 7.26 |
| 8 | 40.84 | 12.31 | 12.91 | 2.99 | 28.53** | 27.93** | 37.85** | —0.60 | 9.32 | 9.92 |
| 9 | 45.33 | 17.81 | 16.28 | 3.83 | 28.52** | 29.05** | 41.50** | 1.53 | 13.98 | 12.45 |
| 10 | 62.17 | 13.00 | 16.78 | 4.33 | 49.17** | 45.39** | 57.84** | —3.78 | 8.67 | 12.45 |
| 11 | 81.94 | 19.09 | 15.12 | 6.51 | 62.85** | 66.82** | 75.43** | 3.97 | 12.58 | 8.61 |
| 12 | 75.23 | 22.50 | 15.75 | 7.80 | 52.73** | 59.48** | 67.43** | 6.75 | 14.70 | 7.95 |
| 13 | 84.03 | 23.39 | 14.03 | 9.36 | 60.64** | 70.00** | 74.67** | 9.36 | 14.03 | 4.67 |
| 14 | 99.95 | 26.38 | 13.30 | 10.76 | 73.57** | 86.65** | 89.19** | 13.08 | 15.62 | 2.54 |
| 15 | 104.94 | 23.59 | 17.82 | 11.40 | 81.35** | 87.12** | 93.54** | 5.77 | 12.19 | 6.42 |

由表上測驗結果觀之，每樹齡之各樹種材積生長量，除麻六甲合歡與其他三樹種在5至15各樹齡間均示正符號之顯著或極顯著之差異外，餘三樹種互相間在各樹齡間並無顯著之差異，即自可知在各樹齡間之麻六甲合歡之生長，均凌駕他三樹種之生長，其他三樹種在各樹齡間之生長尙屬相類似。

## 四、生長趨勢 (The growth tendency)

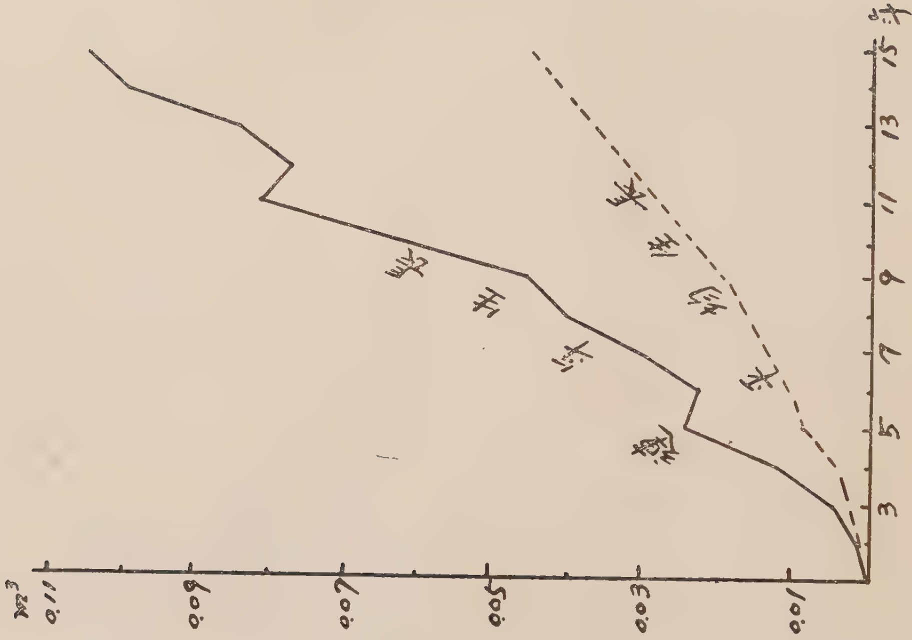
四樹種之生長趨勢，分別由其材積連年生長與平均生長推論之；由第2表之材積平均生長量與第20表材積連年生長量，分別繪出生長曲線圖如第1，2，3，4圖，並分別觀察推論如下：

由第1圖麻六甲合歡之兩生長曲線觀之，其連年生長量每年遞增加速上升，雖於6及12年生稍有跌落，但仍是以呈直線狀急激上升，尙無呈下降，其平均生長曲線，自幼開始略呈等速趨以直線狀而上升，至伐採時未見降下，其連年生長量爲平均生長量之約2.3倍，兩者相隔尙遙，可知其生長尙在旺盛時期，何時可達最大滿期，尙難推定。

由第2圖鐵刀木之兩生長曲線觀之，雖於9至10年生間，其連年生長量稍小呈有跌落，但以後仍是加速上升，與平均生長曲線大體呈爲近似爲直線狀而上升，在15年生之生長量稍有再跌落，但相隔平均生長尙遙，可知其生長仍在旺盛時期，尙難推定其成熟期。

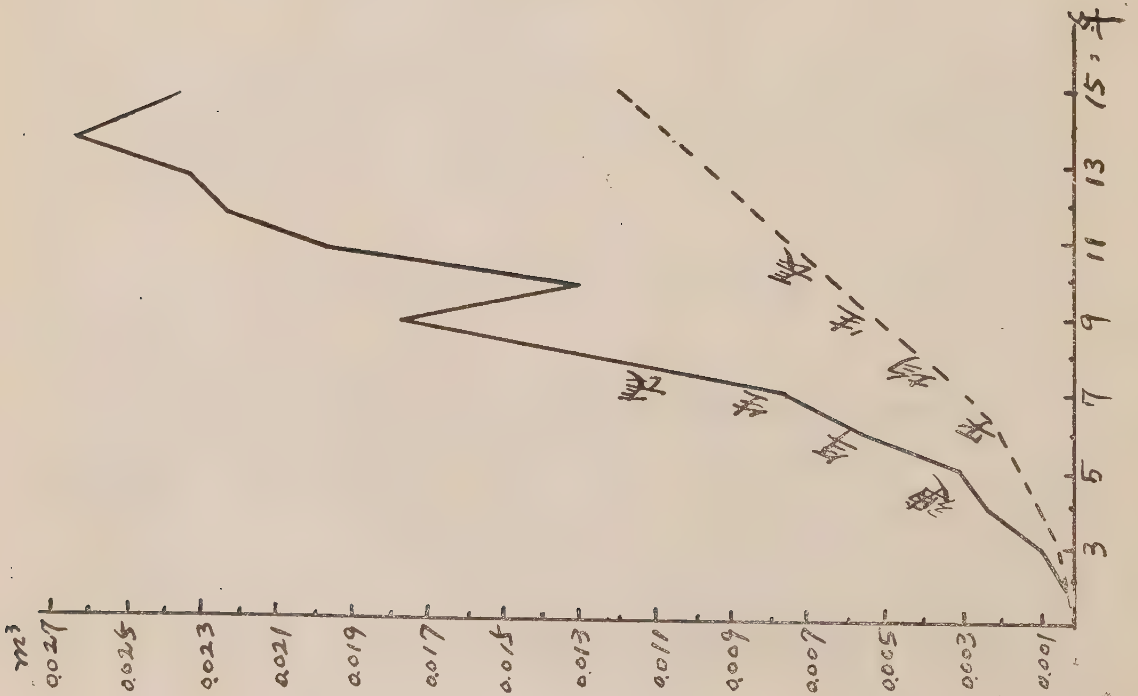
第 1 圖 麻六甲合歡材積生長

(Fig. 1) Current & Mean annual increment of Volume of East India Walnut.



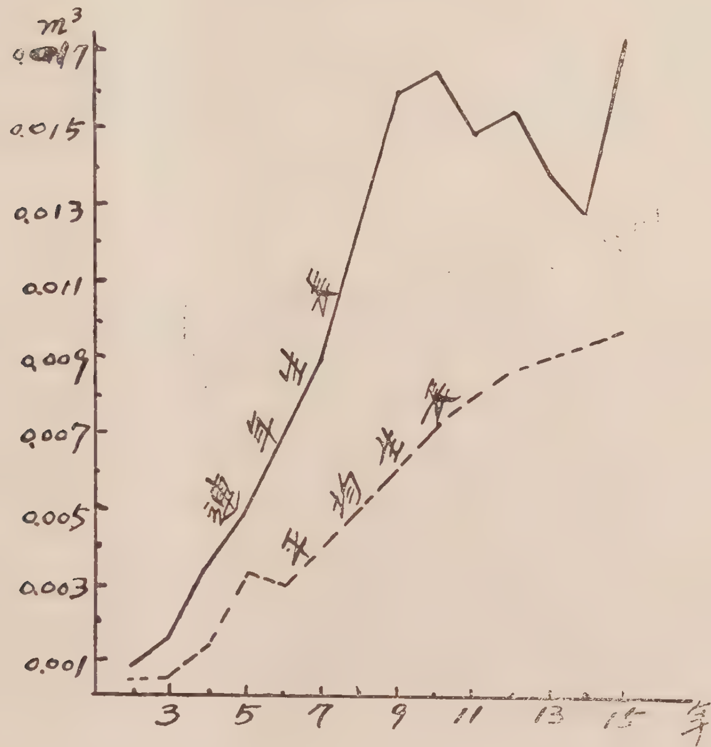
第 2 圖 鐵刀木材積生長

(Fig. 2) Current & Mean annual increment of Volume of Siamese Senna.



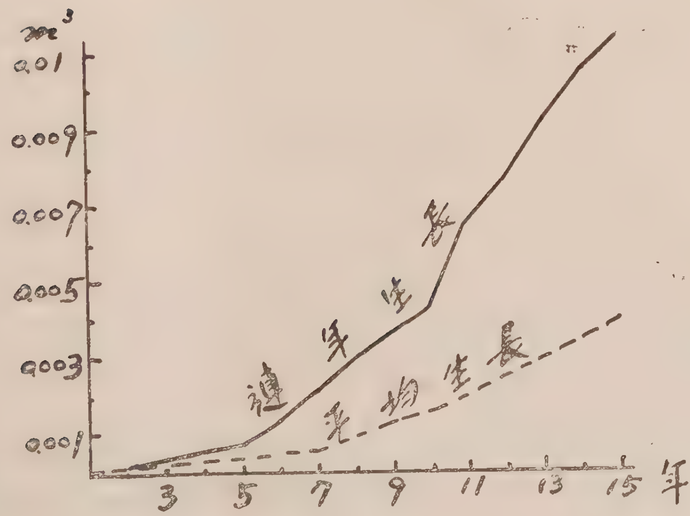
第 3 圖　柚木材積生長

(Fig. 3) Current & Mean annual increment of Volume of Teak.




第 4 圖　印度黃檀材積生長

(Fig. 4) Current & Mean annual incrment of Volume of Sissoo



由第3圖柚木之兩生長曲線觀之，其連年生長曲線，自6年以後略呈爲直線狀而加速上升，雖於12年生時稍有跌落，但大體仍呈加速上升，至伐採時相隔平均生長尚遙，柚木之材積生長即在旺盛時期，尚未見有衰退之現象，相隔成熟期尚遙，生長在旺盛時期。

由第4圖印度黃檀之兩生長曲線觀之，其生長量均較前者小，自幼年起生長緩慢上升，約在10年生時連年生長量加速增多，似以直線狀而上升，且至伐採時未見有衰退之現象，生長量雖較少，但生長仍在旺盛時期，因兩生長曲線尚未見有接近之趨勢，其成熟期無從推知。

總括可知麻六甲合歡等外來樹種之生長，至15年生均未見有衰退之現象，雖印度黃檀之生長量較少爲他樹種，但均相隔成熟期遙遠，生長在旺盛時期，其成熟期現仍無從推知。

## 五、摘　　要 (Summary)

I　各因子之總生長量及平均生長量，均按普通觀察法比較論述其結果分列記述於下：

(1) 各因子之總生長，始終均以麻六甲合歡爲最優，柚木在幼年時較好鐵刀木，但自12年生以後即反之，印度黃檀之生長爲最劣，按材積生長率而言，於幼年時以麻六甲合歡爲最大，印度黃檀爲最小，但均較 100/15 爲大，可證明四樹種之材積生長仍在旺盛時期。

(2) 各因子之平均生長，麻六甲合歡確較他三樹種爲大，鐵刀木，柚木即將次之，以印度黃檀之生長始終最小，但各因子之平均生長量最大時期各有不同，至15年生間綜合列如第27表。

各因子平均生長量最大時期　第27表

| 樹　種 | 樹　高 | 胸高直徑 | 胸高斷面積 | 材　積 |
|---|---|---|---|---|
| | 年生 | 年生 | 年生 | 年生 |
| 麻六甲合歡 | 5 | 11 | 15 | 15 |
| 鐵　刀　木 | 6 | 14 | 15 | 15 |
| 柚　　木 | 2 | 9 | 13 | 15 |
| 印度黃檀 | 2 | 15 | 15 | 15 |

II　各因子之連年生長量，按複合試驗分析法比較其結果：

(1) 樹高：四樹種之連年生長量，以麻六甲合歡爲最大，鐵刀木與柚木相類似，而印度黃檀爲最小；亦各樹齡間之生長量，以 2～10 年生間爲最大，其餘各年生較前列各年生之生長量爲小。

(2) 胸高直徑：四樹種間之胸高直徑連年生長量，麻六甲合歡較大爲其他三樹種，鐵刀木與柚木相彷彿，印度黃檀示最小；各樹齡間而言，3～5 及8～12 各年生爲全樹齡中生長最優時期；又依每樹種之各樹齡而言，麻六甲合歡之最優時期爲5，8年生，以 2年生爲最小，鐵刀木除 5，15樹齡生長較差外，其餘均相彷彿，柚木在 3～11 年生間之生長相彷彿，且爲全樹齡中生長最優時期，反之最劣時期在13～15年生間，印度黃檀有連年遞增之趨勢；再依每樹齡之各樹種間而言，麻六甲合歡與其他三樹種，在各樹齡間大體均示顯著或極顯之差異，示在各樹齡間之生長較優，其他三樹種在3～5，12～14等樹齡間，樹種互相間之生長示正符號之顯著或極顯著之差異外，其餘各樹齡間之生長均示相彷彿。

(3) 胸高斷面積：四樹種間以麻六甲合歡凌駕他三樹種，鐵刀木與柚木均示相彷彿，乃以印度黃檀爲最小，在各樹齡間之生長，以11～15年生間之生長相彷彿，並且爲全樹齡中最優時期，

其餘均較此爲劣，將次之，其中3，4年生示爲最劣。

(4　材積：麻六甲合歡示四樹種中生長最優者，印度黃檀反之示最小，鐵刀木與柚木略相類似；樹齡間之生長，在12～15年生間爲全樹齡中生長最優時期，9～11年生次之，以2～8年生爲最劣時期；依每樹種之各樹齡間而言，麻六甲合歡以14～15等樹齡爲最優，10～13年生次之，2～9年生爲最小時期，鐵刀木以8～15年生爲最優時期，6～7年生次之，柚木及印度黃檀，在全樹齡中均相彷彿；再依每樹齡之各樹種間而言，麻六甲合歡在5～15年生間與其他樹種間爲極顯著或顯著之差異，示其生長確較凌駕他三樹種外，其餘鐵刀木稍見稍優，但其差異無顯著，柚木與印度黃檀，形式上前者略優於後者，但各樹齡間之生長差異不顯著，而示相彷彿大致相同。

## 六、結　　論 (Conclusion)

選擇生長迅速而材質良好之造林樹種，當爲林業經營上之基本原則，故綜合觀察所得結果，生育於亞熱帶圈低海拔區域之紅褐色砂質壤土，表土甚淺瘠劣，保水力量極弱，易於流失之立地條件尙屬不良林地上之麻六甲合歡等四種引進樹種，以麻六甲合歡而言，當15年生，其林相並不正常而其樹高達到24m，胸高直徑27cm，其材積已有0.69m$^3$之多 (但大者高達32m，胸高直徑示有72cm)，雖較與原產地之生長量有相當差異，但於臺灣一般造林樹種而論，罕見有如此生長迅速者。如與生育同一產地之鐵刀木、柚木、印度黃檀等外來引進樹種比較，其各項生長始終以麻六甲合歡爲最優，且於15年生時之材積生長率，乃較100/15爲大，此可證明材積生長尙在旺盛時期；至於柚木在幼年之生長略較鐵刀木適宜於該產地，生長稍大，但以後之生長即示不如鐵刀木；又印度黃檀栽植於新化林場，則對於樹性，立地及殖育法等須重加檢討之必要。

故麻六甲合歡之生長迅速，繁殖容易，雖其材質不强，不適宜充當柱材等力學的用途，但爲優良之板材，邊心材之區別不明顯，常在樹幹發出特殊之臭味，可預防蟲蝕，如供包裝用木箱，合板及板材之用途，並無不相宜，故其推廣造林，在台灣是值的提倡而必要之造林樹種矣。

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## 八、英文摘要 (English summary)

# Comparative Studies on the Increments of East India Walnut, Siamese Senna, Teak and Sissoo in Shin-Hua Forest Experimental Station

by

Tzu-Yu Lin

### English Summary

I. Albizzia Falcata Bacher (East India Walnut; Abbr: Walnut), Cassia siamea Lam (Siamese Senna; Abbr: Siamese. S.), Tectona Grandis Linn (Abbr: Teak), and Dalbergia sisso Roxb (Abbr: Sissoo) are all introduced from forign country into this island. Among which Siamese. S. and Teak are the Popular silvicultural species and play a very remarkable position in Taiwan. The growing condition, the age-gradations and the difference among the species growth in the Forest Experimental Station of the Taiwan provincial Callege of Agriculture at Shin-Hua have not yet been Made.

II. All the sample trees were treated by means of the sectional measurement of Huber's formula for stem-analysis. The growth values of the total and mean annual increments in the same age-gradations of the 4 species were compared by ordinary experimental methods. And the current annual incremnets of their growth on each species were studied by means of "Analysis of complex experiments".

III. Observations of the total and mean annual increments of height, Diameter breast-high (Abbr: D.B.H), basal area and volume of Walnut is largest than those three species, Siamese. S. and Teak is found to be the largest than of Sissoo, and the next to Walnut, Sissoo is the least. But all the 4 species volume increment percentages are higher than the volues calculated by Pressler's determinative rule 100/a.

IV. Analysis of varianes of the current annual increments:

(a) Differences among the species; The height, D.B.H, basal area and volume increment of walnut which grown in Shin-Hua is largest of all, Siamese. S. and Teak in found to be the next, Sissoo is the least.

(b) Differences among the age-gradations: During the age of 2-10 the increment of heingt, 3-5 age and 8-12 age of the D.B.H, 11-15 age of the basal area and volume increment are the four species being the same are found to be the maximum period of all age-gradations, during the age of 12-15 the increment of height and D.B.H, 3-6 age of the basal area and volume increment is the least of all age-aradations.

(c) Species X Age-gradations; Studying among the age-gradations of eeach species, we find no significant different in the height and basal area increment.

Accoding to the experimental conclusion, a 15 years-old Walnut, though its apparance is abnormal has been 24 M in height, 27 cm in D.B.H, and 0.69 $M^3$ in volume (Yet the

largest onc is 32 M in height and 72 cm in D.B.H). As regard to the silvicultural species in Taiwan, it is very race to see such a rapid-gorwth plant as Walnut, notwithstanding its increment is much less than itself plantid in the original land. Walnut, Teak, Siamese. S. and Sissoo all grow at the same Forest Experimental Station and they are introduced from forign country to Taiwan, but Walnut is superion to them in growth, and its volume increment-percentages, within its 15 years growth, is height than 100/15, this proues the volume increment is still in its flourishing period. As to Teak, in the frime of the year is more suitable to this island and grows better than Siamese. S. but at the 15 years the Siamese. S. grows better. With reference to the character, soil-condition and method of cultivation of Sissoo, we find they are necessary to be discussed over again.



第五圖 麻六甲合歡本相
(18年生)



第六圖 麻六甲合歡之胸高直徑



第七圖 與相思樹混淆之麻六甲合歡造林地內
(18年生)



第八圖　鐵刀木造林地
(17年生)



第九圖　柚木造林地
(18年生)



第十圖　印度黃檀造林地
(27年生)

# 氮鉀對黃麻養分吸收量及產量之關係

盛澄淵　楊尚仁

## 一、前　言

作者等在鉀肥對黃麻養分吸收量及產量之關係之試驗時，黃麻產量與麻莖中含鉀百分率與鉀肥用量成正比，在最高用量公頃 150 公斤 $K_2O$ 時，得精洗麻 3,544 公斤；麻莖 $K_2O$ 含量為 1.08%，內麻皮及麻藁各為 1.46% 與 0.81%。除葉中含量不計外，總含量為 199 公斤[1]。惟在該試驗中除化學肥料外，公頃尚施堆肥 10 噸，對試驗正確性受相當影響。又麻類之生育主要受氮鉀之支配，鉀肥與黃麻養分之吸收及產量均受氮肥影响極大，故本試驗目的在純用化學肥料下，研究氮鉀對黃麻養分之吸收與產量之關係，以作進一步之研究。

## 二、田間試驗方法

### （一）處理代號與田間規劃

本試驗公頃氮素用量分 60 與 120 公斤兩等級，氧化鉀量自 0 至 240 公斤間分 5 個等級，磷肥用量均為 60 公斤 $P_2O_5$，詳見表 1。每試區為 4 行區，行長 12m，寬 1.8m，故每試區面積為 $12m \times 1.8m = 21.6m^2$。收獲時，兩邊行不計，但仍稱其重量以資參考，故實收面積為 $12m \times 0.9 = 10.8m^2$。10 個不同處理區為一區集，重複 6 次，每區集內試區，按逢機區集法排列。

表 1　處 理 代 號

| 肥料用量 公斤/公頃 ＼ 處理代號 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_2O$ | 0 | 60 | 120 | 180 | 240 | 0 | 60 | 120 | 180 | 240 |
| N | 60 | | | | | 120 | | | | |

### （二）施肥與田間管理

氮肥用硫酸銨，磷肥用過磷酸鈣，鉀肥用氯化鉀。磷鉀與半量氮肥用為基肥。基肥在播種前施於植溝內，覆以薄土後播種。於播種後二個月內施氮素追肥二次，同時定株及培土，施追肥及培土日期係視苗之發育情形而定。

田間管理依照一般農家管理方法管理之，惟對開花期特別注意觀測，因開花時間不整齊，故每一試區內，任意指定 10 株測定之，其平均値即為該區之開花期。收獲時各區秤測其生莖及生皮重量，每試區並取 3 台斤製精洗麻，以求得精洗麻。並取部份樣品，以供室內分析用。

### （三）試 驗 經 過

本試驗於民國 48 年在台中省立農學院農場舉行。供試品種為水上青皮一號，於 4 月 10 日

播種，5 月 8 日與 21 日分別施追肥各一次，8 月 21 日開始收穫。

## 三、田間試驗結果

### （一）觀察與調查

黃麻生育狀況在收穫前雖未作詳細之調查，然據觀察所得，施鉀氮多量區生長較高，莖徑較粗，至爲明顯。開花期調查整理結果如表 2。表中數字爲各處理播種至開花平均天數。

表 2　施肥與播種至開花天數

| 處　　理 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 各區集平均 | 118.2 | 120.7 | 121.7 | 121.6 | 125.2 | 105.3 | 113.1 | 116.4 | 121.6 | 123.1 |

試觀第 6 處理從播種到開花爲 105.3 天，第 5 處理爲 125.2 天，兩者相差爲 19.9 天，可見處理間之開花遲早受肥料用量之影響甚大。鉀肥用量愈多開花愈遲，氮肥則恰相反。無鉀多氮區縮短生長期，開花較早而影響收量；無鉀少氮區生育期較長，但植株弱瘦，產量減少。

### （二）產量分析

黃麻收穫後分別計算各項產量如表 3。由該表觀之，黃麻產量不論氮肥之用量多少，均隨鉀肥用量增加而增產。在同量鉀肥時，氮肥用量多時產量亦增。黃麻種植之目的在採收精洗麻，故以精洗麻收量爲準再計算氮鉀肥對黃麻之效應如表 4。

表 3　各處理產量（公斤/公頃）

| 處　　理 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | L. S. D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 生　　莖 | | 64074 | 66490 | 68611 | 70620 | 79407 | 72555 | 84036 | 80509 | 91435 | 95203 | 9648.19<br>12851.91 |
| 鮮 粗 皮 | | 21629 | 23759 | 26925 | 26546 | 30324 | 26620 | 30342 | 30870 | 35046 | 36592 | 3787.05<br>5037.06 |
| 乾 粗 皮 | | 4898 | 5194 | 6185 | 6009 | 7249 | 6222 | 7027 | 6842 | 7768 | 8027 | 925.93<br>1240.75 |
| 生　　藁 | | 42444 | 42638 | 41694 | 45157 | 49083 | 45935 | 53685 | 50879 | 56379 | 58620 | 7435.22<br>9898.19 |
| 乾　　藁 | | 13787 | 13879 | 13546 | 14814 | 15944 | 14925 | 17444 | 16268 | 18314 | 16046 | 2416.68<br>3212.98 |
| 精 洗 麻 | | 2705 | 3062 | 3620 | 3665 | 4227 | 3833 | 4380 | 4588 | 5334 | 5622 | 462.04<br>615.74 |
| 精洗麻 | % | 12.24 | 12.87 | 13.43 | 13.70 | 13.93 | 14.39 | 14.44 | 14.86 | 15.23 | 15.37 | |
| | * | 20.74 | 20.89 | 21.50 | 21.73 | 21.97 | 22.28 | 22.32 | 22.67 | 22.99 | 23.11 | 0.[illegible]97<br>0.395 |

* 將原百分率經 $\mathrm{Sin}^{-1}\sqrt{P}$ 變形（查 C. I. Bliss 氏角度與百分率對照表）後用變方分析所得結果。

### （三）氮鉀肥施用之經濟利益估計

若以當時（民國 48 年）之肥料與精洗麻價格計算，每公斤 $K_2O$ 爲 3.83 元（糧食局公斤

氯化鉀配價爲 2.3 元），而物資局收購公斤精洗麻（以二等品計）爲 0.53 元，故每公斤 $K_2O$ 價格等於 0.59 公斤精洗麻。同樣計算氮肥，公斤 N 之價格等於 1.99 公斤精洗麻（以公斤硫酸銨配價 2.6 元計）。參照表 4，公斤氮、鉀肥之增產值，無論氮鉀施用量多少均屬有利可圖。

表 4　氮鉀肥對精洗麻增產之效應

| 處理 | | $N_1$ | | | | | $N_2$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $K_0$ | $K_1$ | $K_2$ | $K_3$ | $K_4$ | $K_0$ | $K_1$ | $K_2$ | $K_3$ | $K_4$ |
| 鉀肥效應 | 產量 公斤/公頃 | 2705 | 3062 | 3620 | 3665 | 4227 | 3833 | 4380 | 4588 | 5334 | 5622 |
| | 產量 指數 | 100.00 | 113.19 | 134.01 | 135.49 | 156.27 | 100.00 | 114.27 | 119.69 | 139.10 | 146.67 |
| | 較無鉀區增產量 公斤/公頃 | — | 357 | 915 | 960 | 1522 | — | 547 | 755 | 1501 | 1789 |
| | 每公斤 $K_2O$ 較無鉀區增產值（公斤） | — | 5.95 | 7.54 | 5.33 | 6.34 | — | 9.11 | 6.2[illegible] | 8.34 | 7.45 |
| | 處理間每公斤 $K_2O$ 增產量（公斤） | — | 5.95 | 9.30 | 0.75 | 9.36 | — | 9.11 | 3.46 | 10.76 | 4.80 |
| 氮肥效應 | 產量 公斤/公頃 | 2879 | | | | | 3959 | | | | |
| | 產量 指數 | 100 | | | | | 137.51 | | | | |
| | 增產量 公斤/公頃 | — | | | | | 1080 | | | | |
| | 處理間每公斤 N 增產量（公斤） | — | | | | | 18 | | | | |

表 5　施用鉀肥之純利

| 處理 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|
| 增加收入（元） | 2331.24 | 5974.95 | 6268.80 | 9638.66 | 3571.91 | 4930.15 | 9801.53 | 11682.17 |
| 鉀肥費用（元） | 230 | 460 | 690 | 920 | 230 | 460 | 690 | 920 |
| 增施鉀肥純收益（元） | 2107.24 | 5514.95 | 5578.80 | 9018.66 | 3341.91 | 4470.15 | 9111.53 | 10762.17 |

再參照表 4 計算各處理鉀肥之純益如表 5。由表 5 觀之，不論氮肥之用量多少，純收益依鉀肥用量之增加而增加，故鉀肥之用量以 $K_2O$ 計，依本試驗之證明可用至 240 公斤。至於施至 240 公斤以上是否再能增加收益，尚待另行舉行試驗。然若參照表 3，10 與 9 處理間差異已不顯著，故實際公頃 $K_2O$ 施用量以 180–240 公斤間爲宜。

## 四、黃麻養分含量分析結果

在收穫時由各試區內逢機取黃麻 2 整枝，撕取麻皮與藁分離後充分乾燥，各別剪短磨成極細粉末以供分析，其結果詳見表 6。由該表觀之，無論麻皮與麻藁，所含要素，均因肥料用量增加而增加，如 1 至 5 與 6至 10 處理間黃麻鉀之含量百分率均順序增加；又 1 至 5 與 5 至 10 各處理平均觀之，公頃用氮量 60 公斤時，皮與藁之含氮百分率各爲 0.1505 及 0.1907，而用 120 公斤時則各爲 0.4574 及 0.52。

表 6　黃麻三要素含量百分率

| 處 | 理 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 皮 | 0.1640 | 0.1731 | 0.1487 | 0.1322 | 0.1343 | 0.4521 | 0.2452 | 0.5305 | 0.5534 | 0.5055 |
| | 藁 | 0.2348 | 0.2515 | 0.1537 | 0.1666 | 0.1379 | 0.4595 | 0.3827 | 0.5123 | 0.6632 | 0.5824 |
| $P_2O_5$ | 皮 | 0.3895 | 0.4395 | 0.4578 | 0.4562 | 0,3953 | 0 3510 | 0.3864 | 0.3231 | 0.3918 | 0.3260 |
| | 藁 | 0.1805 | 0.1771 | 0.2522 | 0.2107 | 0.1785 | 0.1833 | 0.1746 | 0.1799 | 0.2021 | 0.1657 |
| $K_2O$ | 皮 | 0.7656 | 1.1934 | 1.4600 | 1.5518 | 1.7015 | 1.0415 | 1.1034 | 1.2047 | 1.3339 | 1.3602 |
| | 藁 | 0.5570 | 0.8026 | 0.8362 | 1.1476 | 1.1544 | 0.7720 | 0.7779 | 0.9070 | 0.9300 | 1.0577 |

公頃黃麻三要素吸收量除葉根不計外，據表 3 與 6 計算結果如表 7。由該表觀之，不論氮之用量多少，公頃麻莖，鉀之吸收量隨鉀之用量增加。氮之吸收量亦不論鉀之用量多少隨用量而增加，公頃用 N 60 公斤時，吸收量平均爲 35.75 公斤；用 120 公斤時爲 123.42 公斤。若以本試驗最高產量區計算，三要素吸收量各爲 152, 58 及 311 公斤，其比例約爲 1 : 0.38 : 2.1。

表 7　黃麻三要素吸收量(公斤/公頃)

| 處 | 理 | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|
| 1 | 皮 | 8.03 | 19.00 | 37.36 |
| | 藁 | 32.37 | 24.88 | 76.79 |
| | 總 | 40 40 | 43.88 | 114.15 |
| 2 | 皮 | 8.99 | 22.83 | 61.96 |
| | 藁 | 34.90 | 24.58 | 111.39 |
| | 總 | 43.90 | 47.41 | 173.35 |
| 3 | 皮 | 9.20 | 28.31 | 90.30 |
| | 藁 | 20.82 | 34.16 | 113.27 |
| | 總 | 30.02 | 62.47 | 203.57 |
| 4 | 皮 | 7.94 | 27.41 | 93.26 |
| | 藁 | 24.68 | 31.21 | 170.01 |
| | 總 | 32.62 | 58.62 | 263.27 |
| 5 | 皮 | 9.71 | 28.58 | 123.00 |
| | 藁 | 21.98 | 28.46 | 184.06 |
| | 總 | 31.69 | 57.04 | 307.06 |
| 6 | 皮 | 28.13 | 21.83 | 64.80 |
| | 藁 | 68.58 | 27.34 | 115.22 |
| | 總 | 96.71 | 49.17 | 180.02 |
| 7 | 皮 | 18.04 | 28.71 | 81.01 |
| | 藁 | 66.76 | 30.45 | 135.70 |
| | 總 | 84.80 | 59.16 | 216.71 |
| 8 | 皮 | 36.29 | 22.10 | 82.43 |
| | 藁 | 83.34 | 29.26 | 147,55 |
| | 總 | 119.63 | 51.36 | 229.98 |
| 9 | 皮 | 42.99 | 30.43 | 103.62 |
| | 藁 | 121.46 | 37.01 | 170.69 |
| | 總 | 164.45 | 67.44 | 274.31 |
| 10 | 皮 | 40.58 | 26.17 | 109.19 |
| | 藁 | 110.92 | 31.56 | 201.45 |
| | 總 | 151.50 | 57.73 | 310.64 |

## 五、摘要與討論

(一) 本試驗目的在研究黃麻施用氮鉀肥後對養分之吸收與產量之關係。田間試驗於民國 48 年在省立農學院農場舉行。

(二) 以公頃公斤計算，N 分 60 與 120 二級，$K_2O$ 自 0–240 間分五級，組成 10 種不同處理。$P_2O_5$ 均為 60 公斤。

(三) 開花日期受肥料用量之影响甚大，鉀肥用量愈多開花愈遲；氮肥恰相反。

(四) 三要素在麻莖中之含量依施量而異，然不論何種處理，麻皮含 N 百分率均低於藁，磷鉀則均高於藁。皮與藁中 N 與 $K_2O$ 之含量，在其他二要素施用量相等時，均隨該要素用量之多少而增減。公頃 N 用量為 60 公斤時，皮與藁之平均含 N 百分率各為 0.15 與 0.19；用 120 公斤時則各為 0.46 及 0.52。皮中 $K_2O$ 之含量自 0.77–1.7%。若以本試驗最高產區而論，N–$P_2O_5$–$K_2O$ 含量在皮中為 0.51–0.33–1.36%；在藁中為 0.58–0.17–1.06%。依此計算，公頃三要素吸收量為 152–58–311 公斤 (葉不計算在內)，其比例約為 1：0.38：2.1。

(五) 精洗麻之產量，不論氮肥之施量多少，依鉀肥用量之增加而增收。在施等量鉀肥時，施多量氮肥之處理恒較少量者收量高。

(六) 氮肥之增產值因本試驗缺少無氮區，計算困難。若不論施鉀量多少，公頃施用 N 120 公斤時較施 60 公斤者可增產 13.51%；公斤 N 之精洗麻增產值為 18 公斤。以當時之物價計算，公斤 N 等於 1.99 公斤精洗麻，故施用氮，獲利甚厚。

(七) 鉀肥對精洗麻之增產值與純收益如表 8。以當時之物價計算，公斤 $K_2O$ 相當於 0.59 公斤精洗麻，故任何等級鉀肥用量均屬有利。鉀肥用量愈多純利愈高，然因 120–60–180 處理間產量差異並不顯著，故實際公頃 $K_2O$ 施用量至 180 公斤已足。

表 8　鉀肥之增產值與純利

| 施肥量 N–$P_2O_5$–$K_2O$ 公斤/公頃 | 精洗麻產量 (公斤/公頃) | 公斤 $K_2O$ 較無鉀區增產值 (公斤) | 處理間公斤 $K_2O$ 增產值 (公斤) | 每元鉀肥之純利 (元) | 施用鉀肥之純利 (元/公頃) |
|---|---|---|---|---|---|
| 60—60—0 | 2705 | — | — | — | — |
| 60—60—60 | 3062 | 5.95 | 5.95 | 9.16 | 2,107 |
| 60—60—120 | 3620 | 7.54 | 9.30 | 11.99 | 5,515 |
| 60—60—180 | 3665 | 5.33 | 0.57 | 8.09 | 5,579 |
| 60—60—240 | 4227 | 6.34 | 9.36 | 9.80 | 9,019 |
| 120—60—0 | 3883 | — | — | — | — |
| 120—60—60 | 4380 | 9.11 | 9.11 | 14.53 | 8,342 |
| 120—60—120 | 4588 | 6.29 | 3.46 | 9.72 | 4,470 |
| 120—60—180 | 5334 | 8.34 | 10.79 | 13.21 | 9,112 |
| 120—60—240 | 5622 | 7.45 | 4.80 | 11.70 | 10,762 |

## 六、參考文獻

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# RELATIONSHIP BETWEEN THE ABSORBED NUTRIENTS AND YIELDS OF JUTE BY THE APPLICATION OF POTASH AND NITROGEN

by

C. Y. Sheng and S. Z. Yang

## CONCLUSION AND SUMMARY

1. To find out the relationship between the adequate amount of kg/$K_2O$ per ha for the highest production of jute and the absorbed amount of the essential elements ($N$-$P_2O_5$-$K_2O$) are the main purposes of this experiment. It was carried out on the farm of the Provincial College of Agriculture in 1959.

2. In this experiment, two doses of N 60 and 120 kg/ha are applied. Each of which, treated with 0, 60, 120, 180, 240 kg/ha of $K_2O$ and in addition to the same quantity of 60 kg/ha of $P_2O_5$ to make 10 treatments.

3. The experiment shows that the more potash is applied, the later the blooming of jute while the N causes a reverse effect.

4. The absorbed amount of $N$-$P_2O_5$-$K_2O$ in the stem of jute varies with the amount of fertilizer applied. No matter what dose of fertilizer is appiied, the crude bark ot jute contains lower N and higher $K_2O$ and $P_2O_5$ than pith. When the other two elements are added in the same amount, the absorbed amount of N or $K_2O$ in the stem is in relation to the amount of fertilizer applied. It also showed that in 60 kg/ha of N applied plots, the crude bark and pith contained the average amount of N of about 0.15 and 0.19% .Whereas in 120 Kg/ha of N plots they contained about 0.46 and 0.52%. The absorbed amounts of $K_2O$ in crude bark at 5 differet levels of $K_2O$ applied were about 0.77-1.7%, and in the pith, about 0.56-1.15%. From the point of view of the highest yield of jute, the essential elements of $N$-$P_2O_5$-$K_2O$ absorbed by the crude bark are about 0.51-0.33-1.36%, and by the pith, about 0.58-0.17-1.06%. Calculated in terms of kg/ha, they will be 152-58-311 respectively, and are in the ratio of 1 : 0.38 : 2.1 without counting the amounf in the leaves.

5. For any dose of N applied plot, the increasing yields of refined fibres of jute depend upon the amount ot $K_2O$ applied; for the same amount of $K_2O$ applied, the more N is applied, the higher the yield obtained.

6. Because there was the lack of non-N plot as check, it is difficult to calculate the increased yield rate of jute by applying N fertilizer. The average yield increase obtained from N under various treatmenns of potash is 13.5% higher in the plots of 120 kg/ha of N than in those of 60 kg/ha of N. As to the refined fibres, about 18 kg/ha were increased by kg/N. Basing on the costs of refined fibres and fertilizers at the time of the

experiment, one kg/N is equal to 1.99 kg of refined fibres.

7. Table 1 shows the income farmers may obtain and the quantity in kg per ha of refined jute fibres which can be increased by the application of potash.

Table 1. Potasn Increment and Profit obtained thereof

| Treatment $N-P_2O_5-K_2O$ k g/ha | Yield of refined fibres kg/ha | Increment per unit $K_2O$ as compared with no potash kg | Increment per unit $K_2O$ between treatments kg | Net Profit per NT$ of $K_2O$ applied NT$ | Net Profit from potash application NT$/ha |
|---|---|---|---|---|---|
| 60-60- 0 | 2,705 | — | — | — | — |
| 60-60- 60 | 3,062 | 5.95 | 5.95 | 9.16 | 2,107 |
| 60-60-120 | 3,620 | 7.54 | 9.30 | 11.99 | 5,515 |
| 60-60-180 | 3,665 | 5.33 | 0.57 | 8.09 | 5,579 |
| 60-60-240 | 4,227 | 6.34 | 9.36 | 9.80 | 9,019 |
| 120-60- 0 | 3,883 | — | — | — | — |
| 120-60- 60 | 4,380 | 9.11 | 9.11 | 14.53 | 5,342 |
| 120-60-120 | 4,588 | 6.29 | 3.46 | 9.72 | 4,470 |
| 120-60-180 | 5,334 | 8.34 | 10.76 | 13.21 | 9,112 |
| 120-60-240 | 5,622 | 7.45 | 4.80 | 11.70 | 10,762 |

According to both prices of refined jute fibers and fertilizers at the time of experiment, the amount of 0.59 kg of refined fibers is equal to one $kg/K_2O$. So, any dose of $k_2O$ which has been tested in this experiment will bebeneficial to farmers. The higher rate is better. However, the yield difference is not siqnificant between the doses of 120-60-240 and 120-60-180 kg/ha. In general, the dose level of 180 kg $K_2O$ per ha is quite sufficient.

# 紅茶製造過程中化學變化之研究

## Studies on fhe Chemical Changes in Black Tea Manufacturing

徐　大　衡

## 一、引　　言

1892年 M. Kelway Bamber 氏在東北印度，P. VanRomburgh，C.E.J. Lohmann 及 A.W. Nanninga 三氏在爪哇，不謀而合的把茶叶化學研究的目標，從單純的化學分析方面，移轉到複雜的茶叶製造方面(1)。此後四十年間 (1900—40)，繼起研究者；有 H.H. Mann，C. Bernard，P.H. Carpenter，J.J.D. Deuss，C.J. Harrison，K.B.W. Jones，D.I. Evans，W.S. Shaw，D.O. Lams， E.A.H. Roberts 等氏。二次大戰結束後，十餘年來，由於新的分析儀器不斷發明，化學分析方法及技術因之大爲改觀。1948年 A.E. Bradfield 與其工作伙伴，首先將濾紙界面層析法(PaperPartition Chromatography)應用於茶叶分析，證實茶中之單寧成分，確非單純的物質，而是多種不同性質的多元酚類 (Polyphenols) 的混合體(2)-(4)，這一試驗的成功，使製茶化學的研究工作，跨入新的階段。 1955—57 年 E.A.H. Roberts 氏相繼採用兩相濾紙層析法 (Two Dimensional Paper Chromatography) 研究紅茶中酚類物質 (Phenolic Substances) 之存在，及因發酵作用由多元酚類誘導而來的氧化生成物與紅茶品質間的相關性 (5)-(12)。此一研究報導，彌足重視，蓋化學家孜孜不息研究茶叶之目的，端在探求茶中之成分與成茶 (Finished tea) 品質之關係，俾達到建立一合理的科學評茶法，以代替憑人之五官直覺以爲判斷故也。在距今廿年前，作者曾作茶叶分級化學標準之探討，未獲結論，今忽覽及 Roberts 氏之研究報導，不禁怦然心動，爰草斯篇，以就正於同好。

## 二、紅茶製法摘要

在未述本文之前，宜先闡明製造過程中之各個步驟，鮮叶採摘以後，乃舖成一薄層，使之萎凋 (Withering)，普通約經18小時，叶失去水分，乃柔軟易屈，於是開始揉捻 (Rolling)，使細胞破碎，俾擠出之液汁，可曝露於空氣中，同時茶可藉此得到一種特殊之捲曲狀。當叶之組織一經損傷，發酵立即開始，故揉捻與其次一步驟—發酵 (Fermentation)，實無法分開，經一小時半之揉捻後，將叶薄舖於發酵台上，使之發酵，通常約經2至3小時之發酵，即將叶烘焙(Firing)，停止其發酵，並乾燥之。

## 三、萎凋期間之化學變化

鮮叶萎凋之主要變化，爲水分喪失，俾在物理上爲其他製造步驟之準備。但化學變化亦同時發生，此種化學變化，迄今尚無足够令人滿意之解釋。Shaw(13) 氏於其研究茶單寧與紅茶製造之關係一文中，曾作如下之解釋，氏謂鮮叶受到萎凋，乃逐漸喪失其生機，含有果膠質 (Pectin) 的半滲透性細胞膜 (Semi-Permeable Membrance) ，相繼崩裂，於是果膠質，即混合到其他細胞內。萎凋期內的化學變化，泰半受此混合程度的支配。果膠質藉果膠酵素 (Pectase)之活動，發生消酯化作用(De-Esterification)，使萎凋叶產生清香 (Nose)。茶單寧與咖啡鹼 (Caffeine)

原係以游離狀態分別存在於叶之海綿組織及表皮細胞中者，亦因叶細胞滲析現象 (Plasmolysis)，使此二種物質於互相接觸後，化合而成咖啡鹼茶單寧鹽類 (Caffeine-Theotannate)，使鮮叶中含有之苦澁味除去而產生辛濃的性質。退酯果膠質藉Mn金屬離子的介入中間作用而與茶單寧發生聯系，成為金屬將果膠質茶單寧複合體 (Complex)。紅茶泡出液之所以發生乳濁(Creaming down) 現象，即緣於此。

Mann (14)氏首先於鮮叶中發現含有二種不同性型之酵素 (Enzyme)，即過氧化酵素 (Peroxidase) 及氧化酵素 (Oxidase)。當萎凋時，過氧化酵素之活動力，隨萎凋時間之延長而增長，以達到18至20小時之活動力最大，過此即迅速減低。Roberts 及 Sarma (15)二氏曾應用 Guthrie 氏法測定其活動力，獲得在鮮叶為 894 I.U. (每克乾組織量)，萎凋叶為 1293 I.U.，揉捻40分鐘後為 780 I.U. 之結果。(I.U. 係 Indo-Phenol Unite 之縮寫，為一種測定過氧化酵素之單位)。

在萎凋時，鮮叶繼續營呼吸作用，因此有部份炭水化物被消耗，其消耗量約為茶叶全乾物量之4%。叶內蛋白質發生分解作用，據 Roberts 及 Sarma 二氏之研究(16)：氏等先將非蛋白質氮素化合物用85%之酒精自叶中完全抽出，然後用 Kjeldahl 法按時進行測定其結果如下表：

| 萎凋每平方碼舖5½磅葉所需之時間 | 蛋白質氮素 % | 含水量 % |
|---|---|---|
| — | 2.38±0.02 | 74.30 |
| 18 | 2.19±0.02 | 66.82 |
| 42 | 1.88±0.05 | 51.84 |

表中蛋白質氮素之數字係由六個10克茶叶樣品所測出之平均值。

Wood(17) 氏認為萎凋叶內之蛋白質於分裂後，經進一步的新陳代謝 (Matabolic) 變化而產生若干之氨基酸 (Amino Acid)，此與萎凋叶中咖啡鹼含量有顯著之增加，適相吻合。在萎凋時，叶綠素大部份遭受破壞。

## 四、揉捻期間之化學變化

揉捻使叶細胞損傷，發酵作用立即開始。茶叶的發酵作用，係屬於酵素性的氧化作用(Enzymic Oxidation)，此種作用，乃以茶叶中之主要物質多元酚類 (Polyphenolic substances) 為受質 (Substrate)，此類受質，在未受損傷之茶生叶細胞中，係存在於空胞 (Vacuole) 內，而氧化酵素 (Oxidase) 則與叶綠體 (Chloroplasts) (18)共存於原形質 (Protoplasm) 中，在空胞與原形質之間，為一層薄膜 (Membrance) 所隔離，在茶生叶未受損傷時，酵素與受質，不能直接接觸，因此，多元酚類不能發生酵素性的氧化作用，即使生叶萎凋超過其一定之萎凋點(Witing-Point) 時亦然。惟一經揉捻，揉捻可能不致使細胞壁 (Cell wall) 完全破壞，但已足够使易碎之空胞薄膜 (Vacuolar membrance) 破裂，於是空胞之內容物，由於擴散作用 (Diffusion) 而進入細胞質 (Cytoplasm)，酵素與受質互相混合(19)，一經吸收氧氣，立即進行氧化作用。

作者於此，擬將所謂茶叶中之多元酚類畧加說明。茶叶中之多元酚類，近年來始逐漸為人所瞭解，因此，過去甚至於現在仍一貫以茶單寧一名總括之。關於茶單寧一詞，用之於代表茶叶中的一群知與不知的物質，令人感到空洞而複雜，故本文從此處開始，即用多元酚類(Polyphenols) 一詞以代替所謂茶單寧一詞 (Tea Tannin)。至於茶中之多元酚類，於此亦畧作叙述。最先從茶叶中發現有多元酚存在者，為日本過村氏，氏於1929年於茶叶中發現有少量左旋異性兒茶質 (⊖-Epicatechin) (20)。繼之，大島氏於 1933 年則發現有少量沒食子兒茶質 (Gallocatechin) (21)。1935年過氏復自日本綠茶中得到一種結晶狀的茶兒茶質 (Tea Catechin) (22)。1936 年大島氏獲得一種不定形物 (Amorphous)，名之為 Bis (5:7:3':4':5'-Pentahydroxy) Flavanol.。(23)二氏之研究，實開茶叶中知有多元酚類研究之先河。

至1948年 Bradfield 與其工作伙伴，將濾紙界面層析法 (Prper Partition Chromatography) 應用於茶叶分析，從錫蘭綠茶中分離出七種兒茶質(2)-(4)：兒茶質 (Catechin)，左旋異性兒茶質 (⊖-Epicatechin)，沒食子兒茶質 (Gallocatechin)，左旋異性沒食子兒茶質 (⊖-Epigallo-catechin)，左旋異性兒茶質酯 (⊖-Epicatechin gallate)，左旋異性沒食子兒茶質酯 (⊖-Epigallocatechin Gallate)，沒食子兒茶質酯 (Gallocatechin Gallate)。自此以後，關於茶叶中多元酚類之研究，始脫穎而出，十餘年來，研究最力，貢獻最大者，厥爲 Roberts 氏，渠應用兩相濾紙層析法 (Two Dimension Paper-Chromatography)，先後分析茶生叶及紅茶，不獨獲得將近三十種性質不同的多元酚物質，而且揭開茶在發酵進程中多元酚類變化的眞面目，使我們明瞭紅茶泡出液的鮮紅明澈的水色及醇厚鮮美的滋味的來源(5)-(12)。水色與滋味，爲組成所謂紅茶品質 (Quality) 的三大要素之二，決定紅茶品質之優劣，即以此爲審評標準。此二種物質之來源，既已明確，以科學之進步，另一品質要素一香氣，在不久的將來或亦可能獲知其究屬何物？則建立一科學的評茶法，似已在望。

## 五、發酵期間之化學變化

茶叶之發酵，在全部製茶過程中影响於成茶之品質最大，蓋因茶叶之色香味諸特徵，皆係於此時所生成。關於發酵之變化，最初有人認爲係如大麥芽糖化之一類變化，又有人認爲係一種初期之腐敗，及用科學方法研究後，各派學者之見解，亦人言言殊，有謂係單純之化學變化者，有謂爲酵素之作用者，但亦有謂係微生物作用者，迨實驗證明酵素說之無誤，於是此說始一致爲各國學者所公認，而茶叶之發酵，殆由於叶本身中之酵素所引起的氧化作用，亦始告定論。

在發酵時，由叶色之變化及叶內香氣之發展，顯示出化學變化正在進行。茶叶化學工作者，爲探求此一變化之內容，曾費盡心力，努力研討，歷久不輟，直至最近數年來 Roberts氏用濾紙層析法(Paper Chromatography)，研究紅茶發酵進程中多元酚類物質(Polyphenolic substances) 之變化，始獲得證明，所謂茶叶發酵進程中之主要化學變化，乃茶叶中之左旋異性沒食子兒茶質 (⊖-Epigallocatechin) 及左旋異性沒食子兒茶質酯 (⊖-Epigallocatechin gallate)，受酵素性的氧化作用 (Enzymic Oxidation) 而發生氧化之變化(9)，(25)。此二種物質。經氧化後，其衍生物包括下列數群不同性質的物質。

1. 橘棕色呈酸性反應的物質，其含量約爲茶叶乾物量之 10% 以上，Roberts 氏總其名曰 Thearubigins. (24)。

2. 橘黃色呈中性反應的物質，其含量約當茶叶乾物量之2%，Roberts 命其名爲 Theaflavin 及 Theaflavin Gallate.。

3. 無色之 A. B. C, 三種 Bisflavanol.。

4. 含量極微之 Z. Q. P. 三種橙黃色物質。

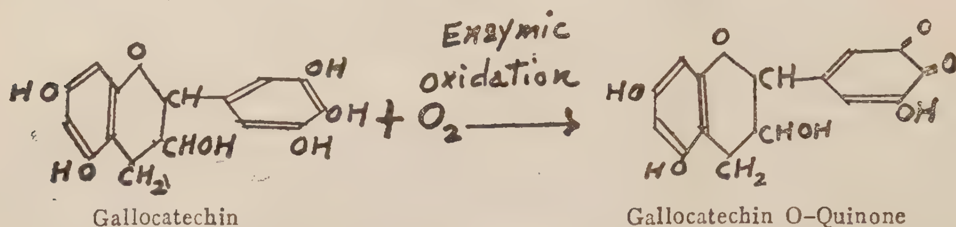
此四羣之氧化生成物，據 Roberts 氏的分析與檢定認爲 (9)-(12)：Theaflavin gallate，Bisflavanol A. 沒食子酸及 Z. Q. P. 六種物質，係自左旋異性沒食子兒茶質酯 (⊖-Epigallo Catechin Gallate) 氧化而來。

Bisflavanol C. 係自左旋異性沒食子兒茶質 (⊖-Epigallocatechin) 氧化而來。

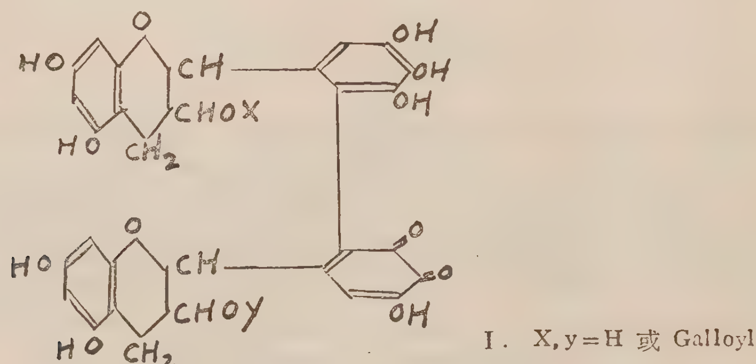
Theaflavin 及 Bisflavanol B. 係自左旋異性沒食子兒茶質 (⊖-Epigallocatechin) 及其酯 (Gallate) 之混合物氧化而來。

Thearubigins 係 Theaflavin 及 Theaflavin Gallate 再經氧化所生成。因此 Roberts 認定此類氧化生成物，係出自同一反應機構 (Reaction Mechanism) (12)。

氏謂：在發酵期間，如茶叶氧化酵素（Tea oxidase）對沒食子酸（Gallic Acid）不發生觸媒氧化作用（Catalyse Oxidation），則初期的酵素性氧化作用，僅有焦性沒食子酚基（Pyrogallolgroup）受到氧化，其初步生成物爲隣位醌（O-Quinone）如下式：

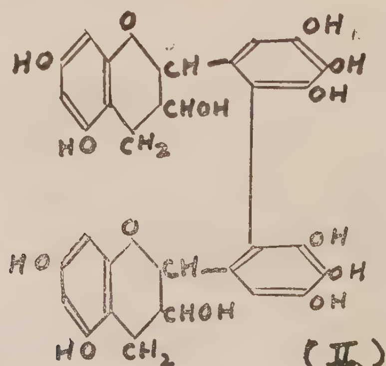



沒食子兒茶質（Gallocatechin）進一步的氧化機構，係由其兩分子隣位醌基之縮合（Condensation）作用，而形成一種二分子式（Dimer）的中間生成物（intermediate），如下列構造式I.（26）




左旋異性沒食子兒茶質（⊖-Epigallocatechin）及左旋異性沒食子兒茶質酯（⊖-Epigallocatechin Gallate）之混合物，經酵素性的氧化作用後，可產生三種有如上式 I. 的中間生成物，其一係來自左旋異性沒食子兒茶質（⊖-Epigallocatechin）的兩分子醌（Quinone）的縮合。其二係來自其酯（Gallate）的兩分子醌的縮合。其三係來自以上兩種受質（Substrate）的各一分子醌的縮合⑿。此類中間生成物之更進一步的轉變如下：

由左旋異性沒食子兒茶質（⊖-Epigallocatechin）氧化所生成之中間生成物 I.（X=y=H），其進一步之轉變，爲使尚未受到變化之受質氧化，而其本身則還原爲 Bisflavanol（Ⅱ）。此被氧化之受質，即相繼形成二分子式的中間生成物 I. 並繼續進行氧化及還原作用，直至左旋異性沒食子兒茶質，完全被氧化爲 Bisflavanol 爲止。（12）

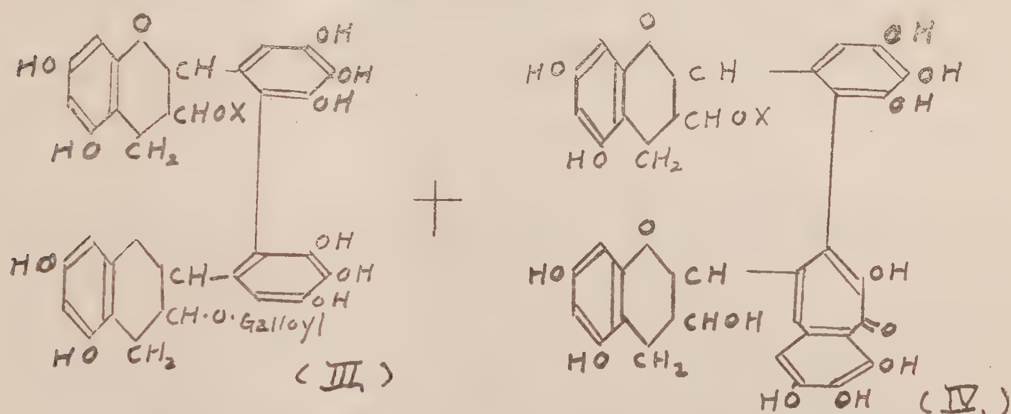


此中間生成物 I.，如係由左旋異性沒食子兒茶質酯（⊖-Epigallocatechin Gallate）（X=y=Galloyl）氧化而來，則其進一步的轉變：係屬互變（Dis mutation）之氧化作用，即中間生成物的一分子被還原爲 Digalloyl-Bisflavanol（Ⅲ）（X=Galloyl），而另一分子則被氧化，氧化時，其所含之 Galloyl Group 亦參與氧化，成爲 Benztropolone，則最後生成物爲含有一個易於水解的 Galloyl group 的 Theaflavin gallate(12)（IV）（X=Galloyl）。

混合兒茶質，經氧化後，於形成具有一個 Galloyl Group 之中間生成物 I.（X=H,y=Galloyl）亦呈互變現象。其中間生成物一分子將還原成爲 Mono-Galloyl-Bisflavanol（Ⅲ）（X=H），另一分子則被氧化而衍生 Benztropolone 成爲 Theaflavin(12)（IV.）（X=H）。

中間生成物 I. 因互變生成Bisflavanols（Ⅲ.）及 Theaflavins（IV.）

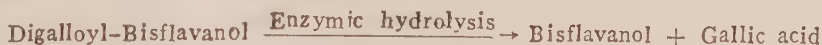



上述之 Digalloyl-Bisflavanol 及 Monogalloyl-bisflavanol 實爲 bisflavanol 的双沒食子酸基（Galloyl）及單沒食子酸基的酯類（Ester）。

Theaflavin gallate 爲 Theaflavin 的酯類。

因此，此三種物質，經酵素的水解作用（Hydrolysis），即分別生成 Bisfavanol 或 Tneaflavin 及沒食子酸（Gallic Acid），其反應程式如下：



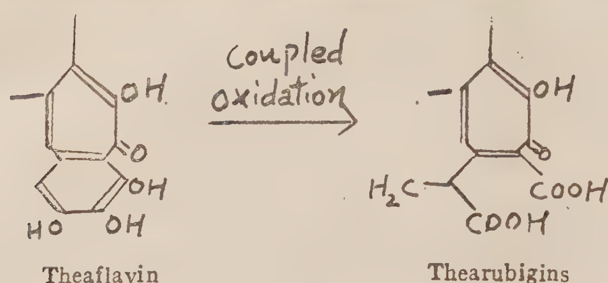






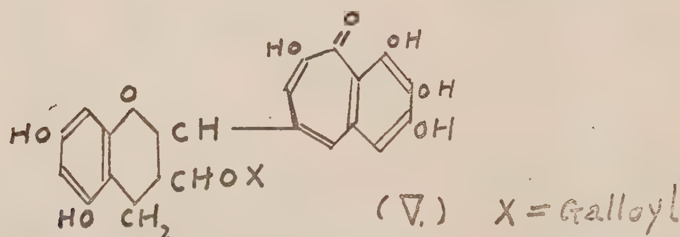

Thearubigins 之生成：

在紅茶抽出液之層析譜上（Chromatogram）的點跡（Spot），以 Thearubigins 的幅度爲最大，表示其含量亦最多 (9), (11)。此物質在過去認爲完全係經由 Theaflavin 及 Theaflavin Gallate 進一步的偶聯性氧化（Coupled Oxidation）而生成，但最近已知，當 Theaflavin 受到偶聯性氧化作用之同時，兒茶質（Catechin），左旋異性兒茶質（⊖-Epicatechin），及左旋異性兒茶質酯 ⊖-Epicatechin Gallate 亦存在於此進行變化之體系中。此類偶聯性氧化的生成物，由 Thearubigins 在濾紙層析譜上，很明顯地可以觀察到 (9), (11)。由 Theaflavin 轉變成爲 Thearubigins 的程式如下：

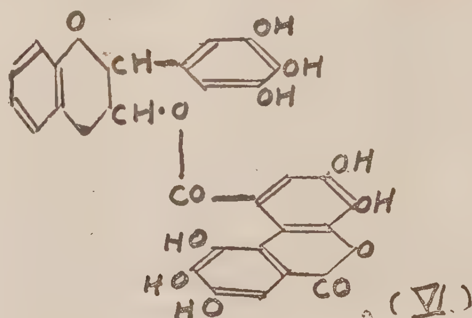



發酵叶中之微量物質：

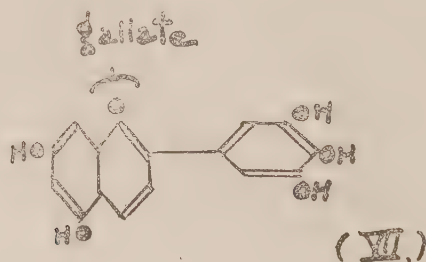
Q. 在紅茶抽出液之濾紙層析譜 (Paper Chromatogram) 上，此 Q 點跡 (Spot) ，表示至少為二種以上物質之混合物。其中之一經認定為焦性沒食子酸紅 (Purpurogallin Carboxylic Acid)，另一物質亦經認定為左旋異性沒食子兒茶質酯 (⊖-Epigallocatechin Gallate) 與 Pyrogallol 之混合物，乃經酵素性的氧化作用而產生的物質(12)，其構造式如下 Ⅴ.：




Z. 為 ⊖-Epigallocatechin Gallate 中之沒食酸基 (Galloylgroup) 與沒食子酸 (GallicAcid)，經氧化縮合作用，而再經 Lactonization 而產生(12)。其構造式如下 Ⅵ.：




P. 乃 5:7:3′:4′:5′-Pentahydroxy-Flavylium Salt，其構造式如下 Ⅶ.



## 六、乾燥過程中之化學變化

乾燥時，因加熱及水分之蒸發，酵素即停止作用，叶中一部份炭水化物發生焦糖化作用 (Caramelization.) ，香精油有若干損失，此物質係在發酵時所生成。當乾燥時，其易於揮發之成分 (Volatile Constituents) ，因加熱而散失。Yamamoto 及 Kato 二氏曾從400克之發酵叶，用蒸氣蒸餾獲得13克之粗芳香油 (12) (Crude Essential oil) ，在乾燥時，蛋白質變爲不溶性。

## 七、結　　論

由於茶單寧的化學組成及性質，有新的認識，因之，有關紅茶製造過程中發酵變化之解釋，已獲得相當明確而可信。過去的一切假說和理論，藉以證實，錯誤的觀念，亦予以廓清。

在左旋異性沒食子兒茶質及其酯之氧化生成物中，以 Thearubigins，Theaflavin 及 Theaflavingallate 最爲重要，此三者在茶叶中含量之總和，約可達茶叶乾物量之 15% ，茶叶泡出液 (Liquor) 之水色 (Colour) 與强烈性 (Strength) ，完全依賴此三種物質決定之。 Theaflavin 及 Theaflavin gallate 含量之高低，並爲決定茶湯滋味 (Taste) 之主要因素，含量高者，茶之滋味亦强。茶之爽快性 (Briskness) ，則決定於咖啡鹼 (Caffeine) 與 Theaflavin 之含量與配合(12)。

因 Theaflavin 及 Theaflavin Gallate 再經氧化則生成 Thearubigins 故發酵時間，必須控制適當，過久則 Theaflavin 及 Theaflavin gallate 之含量減低，Thearubigins 之含量相對的增高，影响茶湯之水色加深，滋味淡薄，爽快消失(12)。

Theaflavin 及 Thearubigins，可用比色法 (Colorimetric Method) 予以測定，如將其測定結果，以與茶師之評價相比較，可獲得明顯之相關，即評價高之茶，其 Theaflavin 含量亦高，反之則低(12)。

紅茶之香氣，包括 Flavour 及 Aroma 二種，前者究屬何物？迄今尙無定論。後者係於發酵時所生成，普稱之爲香精油 (Essential oil)，其含量可達發酵叶之 3% 強，但在烘焙時，多因加熱而逸去(28)。 Romburgh 氏曾用蒸氣分餾法，將此物質分爲二部份，一部份爲無色油滴狀，可就餾出之水面上收集之，具有尖銳之刺鼻香氣 (Penetrating odor) 。

在發酵時，茶果膠質，藉果膠酵素 (Pectin Methylesterase) 的活動，發生退甲基化作用 (Demethylation) ，即水解爲果膠酸 (Pectic-acid) 及甲醇 (Methanol) (29)。故果膠質與紅茶香氣之生成，似亦未可忽視。

總之，製茶化學變化之研究，已進入解決茶叶品質問題之中心，倘百尺竿頭，更進一步，用化學分析方法以釐定茶叶品質，當不在遠，吾人試拭目以待之可也。

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# Studies on the Chemical Changes in Black Tea Manufacturing

By D. H. Hsu.

## Summary

There are four principal processes in the preparation of black tea; namely, withering, rolling, fermenting, and firing.

In withering, the essential change taken place is the loss of moisture, a flaccid condition of the leaves and important changes in the constituents of the cell sap may be summarized as follows:

Dr. Shaw made a further detail study on the pectin, tannin and caffeine: and showed that the pectin may be de-esterified by the activity of the pectase to make withered leaves rich in flavor. He also showed that the free-tannin and the free-caffeine combined together to form caffeine- theotannate compounds which are soluble in the tea infusion to give a pungency or an astringency characteristcs to the tea.

Dr. Mann found two kinds of enzymes in the leaves during withering, i.e. oxidase and peroxidase. the activity of the latter may be increased, as the withering time is prolong within eighteen to twenty hours.

During withering, the shoots continue respiring so that there is a substantial loss of carbohydrate which may amount to as mnch as 4% of the total dry weight. Appreciable protein breakdown also took place and it had been recently shown by Wood that some of the amino-acids produced by proteolysis apparently were subject to further metabolic changes. A breakdown of chlorophyll has been claimed during withering.

Rolling imparts the characteristics of twist and the breakage of the leaf cells, and exposure of juice to the air. From the view point of chemical changes occurred in this process. rolling is intimately connected with fermentation.

During fermentation. it is clear from the marked davelopment of color and aroma that considerable chemical changes are taking place. Roberts studied the changes taking place during fermentation in the water-soluble of the leaf constituents and the analysis by paper chromatography had indicated that the very polyphenols which appeared to have undergone appreciable changes as a result of the fermentation were ⊖-epigallocatechin and ⊖-epigallocatechin gallate.

The. enzymic oxidation of these two substances would be producad some oxidation products. Oxidation of ⊖-epigallocatechin yielded bisflavanol as the main produets. Oxidation of ⊖-epigallocatechin gallate yielded theaflavin gallate and digalloy-bisflavanol as the main products, together with gallic acid and three trace substances, one of these is purpurogallin carboxylic acid and a mixture of ⊖-epigallocatechin gallate and pyrogallol, and another is an oxidative condensation between the galloylgroup of ⊖-epigallocatechin gallate and gallic acid followed by lactonization, and the last one is a 5: 7: 3': 4': 5'

-Pentahydroxy-flavylinm salt. and when a mixture of these two flavanols was oxidized. the products incdude theaflavin and monogalloyl-bisflavanol in addition to these obtained from the individual substances.

Thearubigins are formed as a result of coupled oxidation of theaflavins and its gallates.

Heat. and the removal of moistuie, Practically stop fermentation.

During firing some of the products of the leaf are changed, partial caramelization of the leaf carbohydrates may take place, some of the valuable constituents of the leaf. namely the substances, giving rise to aroma and flavor, may be partially lost in firing. These substances which constitute the essential oil, are volatile in steam. During firing the proteins in the leaf are coagulated and rendered insoluble.

It is probably that theaflavins and thearubigins are largely responsible for the color and strength of tea liquors, and that theaflavins are factors in quality and briskness. A .colorimetric method has bean developed for the estimation of theaflavin ond thearubigins, and the result obtained have correlated well with the valuations of professions tea tasters. in general the highest values are given to teas with high theaflavin values, so long as the thearubigins contents also at a satisfactority high level.

# 四種化學氮肥肥效比較試驗

# EXPERIMENT ON COMPARATIVE EFFECT OF FOUR CHEMICAL NITROGENOUS FERTILIZERS

阮　文　霖

WEN-LIN YUAN

## 一、引　　言

水稻爲臺灣主要作物，氮素爲對水稻之效應最高之營養要素(5)，據1957年之統計資料，消耗於水稻之氮素，佔全省當年氮素總消費量之74%(1)。

氮素肥料種類繁夥，硝酸鹽類由試驗結果顯示其不宜用於水田，然則施於水田之氮肥應屬可供銨態氮素之肥料。

硫酸銨、尿素、氯化銨、氰氮化鈣等四種氮肥，施用後或能直接釋放銨離子，或經分解後可成銨鹽，其對水稻言均屬適宜之氮肥。但彼等性質不同，成分互異，施用後所現之效應難期一致，爰舉行試驗以比較其肥效之高低，供施用上或生產上之擇捨準繩。

臺中地區爲水稻主要栽培地，施用氮肥有顯著增產值，而冬作小麥之栽培面積亦在逐年增加，氮素對小麥之效應亦甚高(4)。爰就臺中地區主要之輪作制度水稻—水稻—小麥進行試驗，以比較硫酸銨、尿素、氯化銨與氰氮化鈣之效應；此外，氰氮化鈣因用作追肥時，需要預行措置，頗費周章，故一般主張氰氮化鈣用爲基肥較爲合宜，因此，本試驗中並比較氰氮化鈣與其他三肥作基肥之果效。本試驗自民國46年第一期水稻開始，連續進行三年，在臺中省立中興大學農場舉行。試驗地土壤爲微酸性砂岩頁岩沖積土，質地屬砂質壤土。根據此地過去舉行之其他試驗，施用氮肥有顯著之增產效果。

## 二、試驗方法

I　處　　理：

表 1　參試處理項目
Table 1　Items of Treatment.

| 處理代號 No. of Treatments | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 基肥 Basic Application | 硫酸銨 Ammonium Sulfate | 尿素 Urea | 氯化銨 Ammonium Chloride | 氰氮化鈣 Calcium Cyanamide | 氰氮化鈣 Calcium Cyanamide | 氰氮化鈣 Calcium Cyanamide | 氰氮化鈣 Calcium Cyanamide |
| 追肥 Top Dressing | 硫酸銨 Ammonium Sulfate | 尿素 Urea | 氯化銨 Ammonium Chloride | 氰氮化鈣 Calcium Cyanamide | 硫酸銨 Ammonium Sulfate | 尿素 Urea | 氯化銨 Ammonium Chloride |

II　試區面積：　水稻　$1.5m \times 8m = 12m^2$

　　　　　　　　小麥　$1.5m \times 7.5m = 11.25m^2$

收穫面積：　水稻 6m²；　小麥 11.25m²

Ⅲ　水稻每小區植　6×32＝192叢，每叢4支，小麥每區三行，每行播種20克。

Ⅳ　參試作物品種：　水稻—蓬萊臺中65號，小麥—台中31號。

Ⅴ　各處理重複八次，計八個區集，田間排列為逢機區集。

Ⅵ　施肥量

表 2　三要素用量（單位：公斤/公頃）

Table 2　Application level of NPK (Unit:kg/ha.)

| 期作 Cropping | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| 一期水稻 1st Rice Crop | 90 | 50 | 50 |
| 二期水稻 2nd Rice Crop | 80 | 50 | 50 |
| 小麥 Wheat | 60 | 50 | 50 |

Ⅶ　施肥法：　磷鉀肥全部均用作基肥；氮肥半為基肥半為追肥。尿素在灌水前三日施用。氰氮化鈣則於施用前一星期與五倍土壤混合并加適量水分使成濕潤狀態後加覆蓋物堆置之。其餘各種肥料均按常法施用。

Ⅷ　田間管理：　照一般慣行法。

Ⅸ　測定土壤反應：　用玻璃電極法。

## 三、試驗結果

本試驗中第一期水稻、第二期水稻，與小麥各有三年之試驗成績，每期作之谷與藁之產量均分別用變量分析法，測定處理間之差異。各期作三年間各處理之谷藁平均產量與差異顯著性比較，分別列於表 3, 4, 5, 6, 7, 與 8, 并分別討論之。

表 3　各種氮肥對第一期水稻谷產量之效應

Tabie 3　Response of Grain of First Rice Crop to Various Nitrogenous Fertilizers.　(1957—1959)

| 年 Year | 處理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處理間差異 Difference Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1957 | 1 | 5578 | (1) | | | | | |
| | 2 | 5260 | 318 | (2) | | | | |
| | 3 | 5155 | 423 | 105 | (3) | | | |
| | 5 | 5128 | 450 | 132 | 027 | (5) | | |
| | 7 | 4885 | 693** | 375 | 270 | 243 | (7) | |
| | 6 | 4728 | 850** | 532* | 427 | 400 | 157 | (6) |
| | 4 | 4465 | 1113** | 795** | 690** | 663** | 420 | 263 |
| 1958 | 7 | 6501 | (7) | | | | | |
| | 5 | 6430 | 71 | (5) | | | | |
| | 6 | 6357 | 144 | 73 | (6) | | | |
| | 1 | 6249 | 252 | 181 | 108 | (1) | | |
| | 2 | 6116 | 385* | 314 | 241 | 133 | (2) | |
| | 3 | 5835 | 666** | 595** | 522** | 414* | 281 | (3) |
| | 4 | 5714 | 787** | 716** | 643** | 535** | 402* | 121 |
| 1959 | 6 | 5080 | (6) | | | | | |
| | 4 | 4845 | 235 | (4) | | | | |
| | 5 | 4775 | 305 | 70 | (5) | | | |
| | 7 | 4727 | 353 | 118 | 48 | (7) | | |
| | 2 | 4492 | 588* | 353 | 283 | 235 | (2) | |
| | 1 | 4477 | 603* | 368 | 298 | 250 | 15 | (1) |
| | 3 | 4470 | 610* | 375 | 305 | 257 | 22 | 7 |

**1% 顯著標誌 (Significant at 1%)。

*5% 顯著標誌 (Significant at 5%)。

上項結果可歸納為下列三點：

1. 硫酸錏、氯化錏、尿素等三種氮肥之效果始終近似；氰氮化鈣之效果，在初期顯著遜於上列三種氮肥，但至終，則與該三種氮肥無顯著差異，以產量言尚且超越約 9%。
2. 氰氮化鈣作基肥之效果，在第一年中畧遜於其他三種氮肥，但其後由迎頭趕上，終而後來者居上。由上述二點結果，足見氰氮化鈣之肥效較為遲緩但持久。
3. 施用氰氮化鈣為基肥時，追肥可用硫酸錏，尿素或氯化錏等之任何一種，蓋其間均無顯著差異。

表 4 各種氮肥對第一期水稻藁產量之效應

Table 4 Respanse of Straw of 1 st. Rice Crop to Various Nitrogenous Fertilizers (1957—1559)

| 年 Year | 處理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處理間差異 Difference Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1957 | 1 | 6425 | (1) | | | | | |
| | 3 | 6352 | 73 | (3) | | | | |
| | 2 | 5862 | 563** | 490* | (2) | | | |
| | 7 | 5790 | 635** | 562** | 72 | (7) | | |
| | 5 | 5479 | 946** | 873** | 383 | 311 | (5) | |
| | 6 | 5258 | 1167** | 1094** | 604** | 532** | 221 | (6) |
| | 4 | 4739 | 1688** | 1613** | 1123** | 1051** | 740** | 519** |
| 1958 | 7 | 7658 | (7) | | | | | |
| | 6 | 7377 | 281 | (6) | | | | |
| | 5 | 7339 | 319 | 38 | (5) | | | |
| | 2 | 7317 | 341 | 60 | 22 | (2) | | |
| | 3 | 7009 | 649* | 368 | 330 | 308 | (3) | |
| | 1 | 6964 | 694** | 413 | 375 | 353 | 45 | (1) |
| | 4 | 6273 | 1385** | 1104** | 1066** | 1044** | 736 | 691** |
| 1959 | 6 | 7672 | (6) | | | | | |
| | 5 | 7669 | 3 | (5) | | | | |
| | 7 | 7567 | 105 | 102 | (7) | | | |
| | 1 | 7362 | 310 | 307 | 205 | (1) | | |
| | 4 | 7178 | 494* | 491* | 3[illegible]9* | 184 | (4) | |
| | 2 | 7167 | 505* | 502* | 400* | 195 | 11 | (2) |
| | 3 | 6920 | 75[illegible]** | 749** | 647** | 442* | 258 | 247 |

**1% 顯著標誌 (Significant at 1%)。

*5% 顯著標誌 (Significant at 5%)。

上項結果可歸納爲下列四點：

1. 四種氮肥之肥效，在開始之年頗有區別，即硫酸銨較佳，氯化銨次之，尿素與氰氮化鈣均顯著落後，尤以氰氮化鈣較其他三種氮肥均有極顯著差異。翌年仍以氰氮化鈣最差，但至終則四種氮肥間已無差異存在。
2. 氰氮化鈣作基肥之效果，開始時顯示不如其他氮肥，但自次年起即脫穎而出，至終其效果反較其他氮肥爲優越。
3. 由本項結果觀之，不論氰氮化鈣單施或用作基肥，其效果均有由劣轉優之趨勢，但單施則遠不如僅作基肥，故氰氮化鈣以作爲基肥較爲合宜，追肥應以其他氮肥補充之。
4. 在以氰氮化鈣作基肥時，追肥可用其他氮肥之任何一種。

表 5 各種氮肥對第二期水稻谷產量之效應

Table 5 Response of Grain of 2nd Rice Crop to Various Nitrogenous Fertilizers (1957—1959)

| 年 Year | 處理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處理間差異 Difference Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1957 | 3 | 4066 | (3) | | | | | |
| | 2 | 4059 | 7 | (2) | | | | |
| | 1 | 4041 | 25 | 18 | (1) | | | |
| | 5 | 4003 | 63 | 56 | 38 | (5) | | |
| | 4 | 3896 | 170 | 163 | 145 | 107 | (4) | |
| | 7 | 3822 | 244 | 237 | 219 | 181 | 74 | (7) |
| | 9 | 3781 | 285 | 278 | 260 | 222 | 115 | 41 |
| 1958 | 1 | 4750 | (1) | | | | | |
| | 2 | 4671 | 79 | (2) | | | | |
| | 5 | 4670 | 80 | 1 | (5) | | | |
| | 3 | 4605 | 145 | 66 | 65 | (3) | | |
| | 6 | 4605 | 145 | 66 | 65 | 0 | (6) | |
| | 7 | 4403 | 347* | 268 | 267 | 202 | 202 | (7) |
| | 4 | 3847 | 903** | 824** | 823** | 758** | 758** | 556** |
| 1959 | 6 | 4136 | (6) | | | | | |
| | 1 | 4095 | 41 | (1) | | | | |
| | 5 | 4020 | 116 | 75 | (5) | | | |
| | 2 | 3991 | 145 | 104 | 29 | (2) | | |
| | 3 | 3869 | 267 | 226 | 151 | 122 | (3) | |
| | 7 | 3865 | 271 | 230 | 155 | 126 | 4 | (7) |
| | 4 | 3756 | 380* | 339 | 264 | 235 | 113 | 109 |

** 1% 顯著標誌 (Significant at 1%)。

* 5% 顯著標誌 (Significant at 5%)。

上項結果可歸納為下列三點：

1. 硫酸銨、尿素與氯化銨等三種氮肥之肥效自始至終均無分別，而氰氮化鈣雖僅在第二年中顯著地較上列三氮肥為差，但其效果經常落後，故當以其較為遜色。
2. 氰氮化鈣作基肥之效果與其他氮肥不相伯仲，而往往較氰氮化鈣單施者畧佳。由是可見氰氮化鈣仍以作基肥為宜，追肥可用任何之其他氮肥。
3. 根據過去數年之試驗，第二期水稻對氮素之效應不顯，此或係本項結果中各處理間無顯明差別之主要原因。

表 6 各種氮肥對第二期水稻藁產量之效應

Table 6 Response of Straw of 2nd Rice Crop to Various Nitrogenous Fertilizers (1957—1959)

| 年 Year | 處 理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處 理 間 差 異 Difference Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 6534 | (3) | | | | | |
| | 2 | 6346 | 188 | (2) | | | | |
| | 1 | 6306 | 228 | 40 | (1) | | | |
| 1957 | 5 | 5948 | 586 | 398 | 358 | (5) | | |
| | 7 | 5931 | 603 | 415 | 375 | 17 | (7) | |
| | 6 | 5747 | 787* | 599 | 559 | 201 | 184 | (6) |
| | 4 | 5531 | 1003** | 815* | 775* | 417 | 400 | 2 6 |
| | 7 | 5935 | (7) | | | | | |
| | 1 | 5912 | 23 | (1) | | | | |
| | 3 | 5895 | 40 | 17 | (3) | | | |
| 1958 | 5 | 5822 | 113 | 90 | 73 | (5) | | |
| | 6 | 5779 | 156 | 133 | 116 | 43 | (6) | |
| | 2 | 5772 | 163 | 140 | 12[illegible] | 50 | 7 | (2) |
| | 4 | 5577 | 358* | 335* | 318* | 245 | 202 | 195 |
| | 1 | 6460 | (1) | | | | | |
| | 2 | 6278 | 182 | (2) | | | | |
| | 7 | 6196 | 264 | 82 | (7) | | | |
| 1959 | 3 | 6126 | 334 | 152 | 70 | (3) | | |
| | 6 | 5992 | 468* | 286 | 204 | 134 | (6) | |
| | 5 | 5991 | 469* | 287 | 205 | 135 | 1 | (5) |
| | 4 | 5736 | 724** | 542* | 460* | 390 | 256 | 255 |

**1% 顯著標誌 (Significanf at 1%)。

*5% 顯著標誌 (Significant at 5%)。

本項結果與穀產量之結果相符，故不另作討論。

表 7　各種氮肥對小麥粒產量之效應

Table 7　Response of Wheat Grain to Various Nitrogenous Fertilizers (1957/1958—1959/1960)

| 年 Year | 處理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處理間差異 Difference Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1957/1958 | 2 | 2473 | (2) | | | | | |
| | 1 | 2381 | 92 | (1) | | | | |
| | 7 | 2336 | 137 | 45 | (7) | | | |
| | 3 | 2326 | 147 | 55 | 10 | (3) | | |
| | 6 | 2230 | 243* | 151 | 106 | 96 | (6) | |
| | 5 | 2215 | 258** | 166 | 121 | 111 | 15 | (5) |
| | 4 | 2124 | 349** | 257** | 212* | 202* | 106 | 91 |
| 1958/1959 | 5 | 1716 | (5) | | | | | |
| | 7 | 1681 | 35 | (7) | | | | |
| | 1 | 1661 | 55 | 20 | (1) | | | |
| | 2 | 1659 | 57 | 22 | 2 | (2) | | |
| | 4 | 1659 | 57 | 22 | 2 | 0 | (4) | |
| | 6 | 1653 | 63 | 28 | 8 | 6 | 6 | (6) |
| | 3 | 1631 | 85 | 50 | 30 | 28 | 28 | 22 |
| 1959/1960 | 2 | 2174 | (2) | | | | | |
| | 1 | 2060 | 114 | (1) | | | | |
| | 5 | 2022 | 152* | 38 | (5) | | | |
| | 3 | 2008 | 166* | 52 | 14 | (3) | | |
| | 7 | 1914 | 260** | 146* | 108 | 94 | (7) | |
| | 6 | 1895 | 279** | 165* | 127 | 113 | 19 | (6) |
| | 4 | 1843 | 331** | 217** | 179* | 165* | 71 | 52 |

**1% 顯著標誌 (Significant at 1%)。

*5% 顯著標誌 (Significant at 5%)。

上表中之結果歸納爲下列二點：

1. 尿素最佳，硫酸銨次之，氯化銨再次之，但此三肥間之差異均未達顯著點而氰氮化鈣則爲四種氮肥肥效最低者，且與其他三肥之差異皆達顯著點。
2. 氰氮化鈣作基肥之效果遠不及尿素之效果，至於與硫銨，氯化銨比較，互有優劣，并無顯明差別。但較之氰氮化鈣單施者似稍優越。

表 8 各種氮肥對小麥稈產量之效應

Table 8 Response of Wheat Straw to Various Nitrogenous Fertilizers (1957/1958—1959/1960)

| 年 Year | 處理 Treatment | 平均產量 公克/小區 Average Yield Gm/Plot | 處理間差異 Differerce Among Treatments | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1957/1958 | 3 | 2470 | (3) | | | | | |
| | 1 | 2466 | 4 | (1) | | | | |
| | 2 | 2386 | 84 | 80 | (2) | | | |
| | 7 | 2264 | 206** | 202** | 122 | (7) | | |
| | 4 | 2198 | 272** | 268** | 188* | 66 | (4) | |
| | 6 | 2058 | 412** | 408** | 328** | 206** | 140 | (6) |
| | 5 | 2037 | 433** | 429** | 349** | 227** | 161* | 21 |
| 1958/1959 | 6 | 2036 | (6) | | | | | |
| | 5 | 1935 | 101 | (5) | | | | |
| | 1 | 1934 | 102 | 1 | (1) | | | |
| | 4 | 1917 | 119 | 18 | 17 | (4) | | |
| | 7 | 1914 | 122 | 21 | 20 | 3 | (7) | |
| | 2 | 1911 | 125* | 24 | 23 | 6 | 3 | (2) |
| | 3 | 1846 | 190** | 89 | 88 | 71 | 68 | 65 |
| 1959/1960 | 2 | 2526 | (2) | | | | | |
| | 1 | 2318 | 208* | (1) | | | | |
| | 5 | 2318 | 208* | 0 | (5) | | | |
| | 3 | 2284 | 242* | 34 | 34 | (3) | | |
| | 4 | 2196 | 330** | 122 | 122 | 88 | (4) | |
| | 6 | 2144 | 382** | 174 | 174 | 140 | 52 | (6) |
| | 7 | 2094 | 432** | 224* | 224* | 190 | 102 | 50 |

**1% 顯著標誌 (Significant at 1%)。

*5% 顯著標誌 (Significant at 5%)。

上表之結果可歸納為下列二點：

1. 四種氮肥之肥效，以尿素最佳，硫酸銨次之，氯化銨再次之，氰氮化鈣最差，而氰氮化鈣有由劣轉佳之趨勢，故至終僅尿素顯著著居於最優之地位，而其他三肥則無顯著差异。
2. 氰氮化鈣作基肥之效果不如其他氮肥，但至終除不及尿素外，與其他氮肥單施或氰氮化鈣單施相較均無顯著差異。

綜合粒產量與稈產量之結果，可見氰氮化鈣作追肥時，對粒之影響較大，對稈之影响小。

試驗地之土壤在開始試驗前採取土樣一次，其後於每年小麥試驗後亦各採土樣一次以分析各試區之土壤 pH 值藉明不同氮肥對土壤反應之影响，歷次測定結果列於表 9。

表 9　試驗前後之土壤 pH 值

Table 9　pH Values of Soil Before The Experiment and After Harvest of Each Wheat Crop

| 處　理 Treatment | 46年2月 Feb. 1957 | 47年2月 Feb. 1958 | 48年2月 Feb. 1959 | 49年2月 Feb. 1960 |
|---|---|---|---|---|
| 1 | 6.50 | 5.90 | 6.30 | 5.50 |
| 2 | 6.25 | 6.10 | 6.50 | 6.15 |
| 3 | 6.20 | 5.85 | 6.20 | 5.90 |
| 4 | 6.30 | 6.40 | 6.60 | 6.40 |
| 5 | 6.50 | 5.90 | 6.00 | 6.00 |
| 6 | 6.30 | 6.10 | 6.15 | 6.25 |
| 7 | 6.15 | 6.00 | 5.80 | 6.15 |

上項結果可歸併爲下列三點：

1. 施用硫酸銨與氯化銨後，土壤之pH值有降低之趨勢，以前者較劇。
2. 氰氮化鈣之施用有提高土壤pH值之趨勢，但在僅用之爲基肥時，則無增減。
3. 不論pH值之變化爲何，僅可見其趨勢，但并無影响及肥效之明顯徵象。

## 四、摘要與結論

I　本試驗自民國四十六年第一期稻作開始，在臺中中興大學農場舉行，以水稻—水稻—小麥之輪作制度進行，連續舉行三年，至民國四十九年三月完成。

II　試試驗目的有二：

A. 比較硫酸銨、尿素、氯化銨與氰氮化鈣對水稻與小麥之肥效。

B. 比較氰氮化鈣和其他三種氮肥的基肥之效果。

III　試驗內設七種處理，各重複八次，田間排列用逢機區集法處理內容如下表：

| 處　理 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 基　肥 | 硫酸銨 | 尿　素 | 氯化銨 | 氰氮化鈣 | | | |
| 追　肥 | 硫酸銨 | 尿　素 | 氯化銨 | 氰氮化鈣 | 硫酸銨 | 尿　素 | 氯化銨 |

IV　就第一期水稻言，不論谷實或桿藁，硫酸銨、尿素、氯化銨間皆無顯著差異，氰氮化鈣在試驗之初期效果較差，但二年後其效果可與前列三肥相埒。氰氮化鈣作基肥而追肥用其他三種氮肥時，其效果與該三種氮肥單用者相較猶有過之。

V　在第二期水稻中，硫酸銨、尿素、氯化銨再度現出相同之效果，而氰氮化鈣單用之效果雖

較落後，但如用爲基肥而以其他氮肥作追肥，其果效可與前三肥比擬。

Ⅵ　以小麥言推尿素之肥效最高，硫銨次之，氯化銨再次之，而以氰氮化鈣最差，氰氮化鈣即作爲基肥亦不相宜。

Ⅶ　試驗前後及中間共採取各試區土樣四次，測定其 pH 値，由測値之平均結果，可見施用硫銨與氯化銨有降低土壤 pH 値之趨勢；施用尿素者 pH 之影响不大，施用氰氮化鈣者有增高土壤 pH 之趨勢，而氰氮化鈣如僅作基肥而以其他氮肥作追肥，土壤 pH 値最爲穩定。

Ⅷ　綜合第一期水稻，第二期水稻，小麥及土壤 pH 測値之結果，爲求獲得持續之利益，各期作氮素肥料之施用，似以下列方式較爲合理：第一期水稻基肥施用氰氮化鈣，追肥施用硫酸銨尿素或氯化銨均可；第二期水稻基肥施用氰氮化鈣，追肥施用硫酸銨，尿素或氯化銨；小麥基追肥均施用尿素。

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## 六、附　　言

臺灣省糧食局補助試驗費用；國家長期發展科學委員會核撥研究補助費；盛教授澄淵懇切指導與校正本文，一一感甚，併此致謝。

## 七、英 文 摘 要

# EXPERIMENT ON COMPARATIVE EFFECT OF FOUR CHEMICAL NITROGENOUS FERTILIZERS

by

Wen lin Yuan

Summary

Experiment for the purpose of comparing the relative effect of four chemical nitrogenous fertilizers such as ammonium sulfate, urea, ammomium chloride and calcium cyanamide on the rice and wheat had been carried out, starting from first rice crop of 1957 and ending with the wheat crop of 1959 totalling in 9 crop cultures in accordance with the rotation system of rice-rice-wheat at the light acid sandstone and shale alluvial soil of Taichung.

The soil pH values of the plots before the experiment and after harvesting of each wheat crop were determined so as to interpret the soil reaction to various nitrogenous

fertilizers in terms of soil pH.

The treatments included in the experiment are listed in the table 10.

Table 10. Numbers of treatments

| Treatments | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| basic application | Ammonium sulfate | Urea | Ammonium chloride | calcium cyanamide | | | |
| top dressing | ammonium sulfate | urea | ammonium chloride | calcium cyanamide | ammonium sulfate | urea | ammonium chloride |

The result obtained may be summarized as follows:

1. On the first rice crop, there were no any significant difference existed between the effect of ammonium sulfate, urea, and ammonium chloride, but they all gave better results than calcium cyanamide, on grain as well as on straw. When calcium cyanamide, however, only used in basic application, and the top application was complemented with any one of three other nitrogenous fertilizers, had shown somewhat better result than others.

2. On the second rice crop, the ammonium sulfate, urea and ammonium chloride also showed no difference, and the effect of calcium cyanamide proved to be the lowest one. The latter was only used in basic application, and top dressing was complemented with others, showed the same result as former ones.

3. On the wheat crop, it was found that the effect of four various nitrogenous fertilizers had showed the different results in accordance with the following order: urea, ammonium sulfate, ammonium chloride, and calcium cyanamide lowest.

4. The tendency may be obviously seen that the application of ammonium sulfate and ammonium chloride caused a drop of soil pH; calcium cyanamide caused a rise of soil pH; urea showed no influence to the pH of soils.

For permanently effective use of chemical notrogenous fertilizers to the light acid paddy soil, according to the experiment conducted in a period of 3 years, the recommendations are suggested as follows: For first and second rice crop, applying calcium cyanamide as basic application in combination with top dressing of ammonium sulfate. ammonium chlorid or urea is Recommended. For wheat crop, urea is most prefered.

# STUDIES ON SOME DISEASES OF ECONOMIC PLANTS CAUSED BY DIPLODIA IN TAIWAN

# I. DIPLODIA BOLL BLACK ROT OF COTTON[1]

By

T. C. Lo[2]

## CONTENTS



## I. INTRODUCTION

The planting of cotton is said to have begun in Taiwan in 1914. However cotton growing did not become a prosperous occupation due to damage from typhoons and due to losses caused by diseases and insect pests.

So to develop the cotton-wearing industry, studies were made on the cotton planting in order to extend self-sufficiency in this material for local needs. Significant results such as selection of the varieties, efficiency direction of investigations and extending them to study disease and insects control, and improvements in the techniques of planting,etc., were then obtained. Since the initiation of these studies the amount of the yield, has been increasing year by year. For example. 780,932 kg. were harvested in 1956, and crop production which totalled 4,427,329 kg. was recorded up to 1959. In fact seventy-five million pounds of short fiber cotton and five million pounds of long fiber cotton are required each year in Taiwan according to the record of Cotton Products Bulletin in 1959. Seventy million pounds or a little more are not enough to meet the local needs so seventy million U. S. dollars had to be sacrificed in foreign exchange to import cotton from the

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(1) Much help was given me in work connected with this paper by Mr. Y.S. Han and Mr. Ho Chung and I wish to express my thanks to them here.

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international market ( 3 ). As is well known the cotton-wearing industry in Taiwan has greatly developed. This industry not only takes care of the needs of this province Taiwan but also can supply cotton goods for export which bring in foreign exchage, because of their excellent quality. Thus, there is no doubt that the national economy and the livelihood of the masses have been benefited.

The cotton planting area increases yearly in Taiwan, and investigation should be made of whether the amount produced per unit area is increasing or not.

According to field surveys, it is evident that diseases, especially the boll black rot caused by *Diplodia gossypina* Cooke, seriously occurred in most of the cotton growing localities. This disease greatly lowers the quality and capacity of cotton production. Intending to remedy this condition, the author devoted himself to carrying on these studies, in the hope of increasing cotton production and cutting down the waste of foreign exchange.

The present paper gives in detail the results on some of the studies on *Diplodia* boll black rot made from 1959 to 1961. The author hopes that his modest efforts will draw attention to the importance of studies on cotton diseases and stimulate interest which can lead Taiwan to supplying its own cotton in an abundance which will adequately meet its needs.

## II. LITERATURE REVIEW

Boll black rot of cotton was first found by Cooke at Bombay, India in 1879. The causal fungus was named by Cooke as *Diplodia gossypina* Cooke and as this name has become established by use of Edgerton and use of others until now. The importance of *Diplodia gossypina* Cooke as cause of boll black rot of cotton had been pointed by Edgerton (1912) who denoted that the disease occurred commonly and was destructive in cotton-growing localities of Louisiana. In 1924, *Diplodia* boll black rot of cotton (*D. gosspiyna*) was responsible for serious reduction (up to 30 to 40 per cent.) of the crops in the central and eastern districts of the U. S. A. after heavy rain during latter part of August (5).

Cook (1925) recorded that the boll black rot of cotton which occurred in Puerto Rico is caused by *D. gossypina* (5). Tucker (1925) also recorded cotton boll black rot is caused by *D. gossypina* (29). Toro (1926) reported that surprising fall of cotton bolls (up to 20 per cent.) observed in the coastal districts of Puerto Rico was attributed at first to the attacks of *D. gossypina*. And he denoted that since an insufficiency of moisture in the soil during the flowering and fruiting periods is considered to be the principal cause of the droping, methods of control should be based on the conservation of soil moisture. But he did not point out the dropping of the boll caused by *D. gossypina* is affected by the moisture (28). Stevens (1926) reported that *Physalospora rhodina* (Berk. & Curt) Cooke is perfect stage of *Diplodia natalensis* Pole Evans and *D. gossypina* (24). Wallace (1928) reported that the fungi found on diseased bolls of cotton at Shinyangan, Tanganyika, in 1926 were *D. gossypina* and the others (30). Eddin (1930) reported that *Diplodia frumenti*, Ell. & Ev. (*Physalospora zeicola* Ell. & Eu.) causes an ear and stalk rot of corn in Florida.

He indicated *D. natalensis, D. tubericola,* (E. et. E.) Taub, and *D. gossypina* also cause a dry rot of ears if they are artificially inoculated when in the rough stage. The symptoms of the ear rots caused by these species are similar to those caused by *D. frumenti.* The four organisms mentioned above, can not be distinguished from each other in their imperfect stage, and they resemble each other in their nutritional, temperature relations, and growth on media of different hydrogen-ion concentrations. They also produce the same type of rot in oranges, grapefruits, sweet potatoes, and watermelons (6). Wallace (1930)reported that *D. gossypina* and *Glomerella gossypii* give a higher rate based on isolation from diseased bolls, and he denoted *D. gossypina* is more common pathogen of the cotton seeds when germination takes place in dishes (31). Eddins (1930) concluded that *D. natalensis* and *D. gossypina* are synonymous and have *Physalospora rhodina* as the perfect stage. *D. frumenti* and *D. tubericola* are tentatively considered two distinct species because their perfect stage are unknown (8). Walker (1930) recorded that boll black rot caused by *D. gossypina* was one of the most serious disease attacking cotton in Florida. He reported that the loss from which in Florida during the wet season of 1928 was estimated at 20 per cent. of the crop (32). Neal & Gilbert (1935) denoted that cotton boll black rot is caused by *D. gossypina* (18). Stevaert (1936) Studies conducted in the Belgian Congo in 1934-1935, pointed out that an affection of the carpel is due to *D. gossypina* (27). Miller's (1938-1939) survey in Virginia, North Carolina, South Carolina, Georgia, and Mississippi was made to obtain data regarding the prevalence and relative distribution of fungi associated with cotton boll black rot. The results show that *D. gossypina* is one of the pathogens, and he denoted that long periods of dry weather were unfavourable to boll black rot (15, 16). Ling (1644) demonstrated that cotton grown in north part of the Szechuan province, China, is stated to suffer most commonly from boll black rots caused by *Gibberella fujikuroi, Diplodia gossypina,* and others, and he noted that in the boll stage a very dry condition almost entirely eliminated the boll black rot (11,33). Marsh et al (1949) reported fungus attack caused serious reduction in yield and quality of cotton fiber during boll opening in 1949 in the vicinity of Florence, South Carolina. The trouble was largely due to species of *Diplodia* and due to *Glomerella gossypii,* both of which were associated with a symptom complex designated"fungus tight lock". Typical *Diplodia* boll black rot was also prevalent. He concluded chemical defoliation give major decreases in the percentage of bolls with *Diplodia* boll black rot and "fungus tight lock" (13). Marsh et al (1951) obtained results from the studies on "The Influence of Weathering and of Microorganisms on the Aqueous pH of Cotton Fiber" which indicated that common *Diplodia* "tight lock" (*D. gossypina*), serious fiber weakening and disintegration were accompanied by pH levels from 5.6 to 6.8 (14). Lehman (1951) reported "fungus tight lock" of cotton (*Diplodia gossypina* and *Glomerella gossypii*) occurred mainly through insect injuries, and he indicated that elimination of insect damage would be more effective as a control measure(9). Parris (1952) demonstrated stem end rot of watermelons is caused by fungus *Physalospora rhodina* (B. & C.) Cooke. He suggested that this organism also causes disease of sweet

potato, ear and stalk rot of corn, boll black rot of cotton and gumming of citrus (19). Arndt (1953) reported *D. gossypina* is one of the principal fungi associated with tight lock of seed cotton in South Carolina in 1952. The causal fungus was relatively more abundant on small, bense, black than on longer tight locks. The pH of the locks varied with the fungi involved, the mean value of those infected by *D.gossypina* being 7.9 or lower (4). The disease record in Taiwan was begun in 1938, as Miyake recorded in Taiwan Agricultural Products, Plant Disease & Insect Prevention, part V, "Cotton Diseases" that the causal fungus of the black rot is infected by wound of mechanic injuries or wound damage by insects. The symptoms which he denoted were that the outer portion of the diseased bolls becomes hard and solid, and carbonaceous. Black colored pycnidia appear abundant on the surface of the bolls (17). Another paper reported by Yung-peng Tsai at Tainan Cotton-Hemp Experimental Station in 1954 which pointed out that the black rot of cotton bolls were caused mainly by *D. gossypina.* The results on surveys obtained in Yulin, Chiayi and Tainan which indicate that the black rot causes more than 50% among the diseased bolls. Yung-peng Tsai and Chiang-hai Yu (1959) reported the results on survey in 1958 that the black rot is a most serious disease among the diseased bolls. Among 158 dried bolls, there were 150 bolls affected by black rot, and among 18 undried bolls, 10 of them were caused by black rot. And he indicated that the damage of pink bollworm (*Pectinophara gossypiella* S.) which occurred in different cotton growing localities of Taiwan may lead to the serious occurrence of black rot (2). Yung-peng Tsai (1958) obtained experimental results from three types of the tests on the reaction of fungicides with the black rot fungus in laboratory which indicate that an organic mercuric compound is better than a copper compound for killing of the spores and the mycelium of the causal fungus. The results especially of both the Granosan and Yamamoto micron emulsions, would be better if the effective component of the organic mercuric compound were increased (3). Other referenes to the black rot will be mentioned later in this paper in their respective paragraphs and sections.

## III. MATERIALS AND METHODS

The investigations herein reported were carried out in the field and in the laboratory. Field studies, carried out in 1958 to 1961, involved observations of the disease on plants and collection of the diseased samples. The laboratory phase involved in microsopic examination of the morphology of the causal organism, artificial inoculations and its observations on stages of the symptom in their development, cultural characteristics, fungicidal treatment, etc.

The causal organisms provided in present investigations were isolated from diseased bolls on cotton plants growing at Hsingsheh, Taichung in September, 1959. To determine whether infection had occurred, inoculation attemps were made by using active pycnospores on bolls collected from the field and by using mycelium prepared in vitro on wounded and

unwounded cotton bolls. Potato sucrose agar was generally used as a routine medium in studies of cultural characteristics. For cultural studies both solid and liquid media were employed. Cultural studies involved temperature in relation to the growth of the colony, different media on growth of the colony, nitrogen and carbon sources in relation to the growth of the causal organism. However, experiments on the effect of temperature on germination of pycnospores were also carried out. To select an effective chemical for control the disease in the field, fungicidal treatment with pycnospores and mycelium were carried out. 18 products with different components of fungicides were used in the investigation. They are Ceresan, Riogen, Bordeaux mixture, Agrosan, Fumilon, Dithane-S-31, Dithane M-22, Dithane Z-78, Perenox, Fermate, New Improved Granosan, Ruberon, Zerlate, Micron, Tuzet Wettable powder, Orthocide-75, King Mercuric Bordeaux, and Phygon XL.

Detailed description of materials and methods used will given later in the appropriate paragraphs and sections.

## IV. EXPERIMENTAL RESULTS

### A. Symptoms

The symptoms, under favorable conditions, appear within 2 days after infection takes place. About 13 days later, the surface of the diseased bolls presents of a mass fungus hyphae in which pycnidia are often imbedded. The following fivefold division of stages is made to describe the evolution and expansion of the symptoms on cotton plants, (See plate I～IV).

1. Primary infecton stage: The diseased portion looked water—soaked at the incipient stage and then turned to dark color with a slightly shining area in the central part. The spot area may gradual extend to the apex or may advance along the surface of the boll which forms a square, if the causal organism attacks the sutures between carpels. The spots are irregular in form when the causal organism encroached through wounds. If it attacks through the hole injured by pink boll worm, however, most of the spots are round because of the insect hole is round. Sometimes, the spots connected with each other which result in making the area of the spot to be irregular and enlarged. At this stage, the color is comparably dark in the inner parts of the carpels. The waste cotton and cotton seeds have yet not been changed (see plate I, Fig—1).

2. Soft rot stage: As the disease portion continues to develop into peach form and the spot area enlarged to occupying half of the whole surface of the boll, becomes soft rot with mold, and is black in color. Under certain conditions, in general, white mold of aerial hyphae may be produced abundantly on the original part of infection. The inner portion of the carpels are dark-greenish colored at this time. The septa of the chamber in the capsule (boll) are dark-green in color and all have adhesive qualities. The waste cotton damaged by pink bollworm is yellow-brown colored (see plate I, Fig-2; Plate II, Fig—1).

3. Late stage of soft rot: The threads of the causal organism continue to run within tissues of the boll, the resulting in the entire decay of the boll. The carpels were densely adhesive with mold flavour, and the aerial hyphae on the surface grow rapidly and abundantly. On the observation of the dissected bolls, it is clear of that inner portion and the apex of the carpels are darkened and are often seriously dacayed; septa of the carpels become soft rot with brownish color. Parts of the waste cotton and of the cotton seeds, when the aspect of a case of disease continues to advance, become soft rot with dark-greenish color in the external view.

4. Dry rot stage: At this stage, the aerial hyphae decreased. The diseased boll became brown, lost their shine, dried up gradually, became and rough on the surface, showed no expansibility, and finally shriveled. On such bolls, the white mycelium of the fungus visible on the surface of the carpels in this time is recognized by the presence of pycnidia on its surface. On the other hand, the apex of the bolls were cracked graudally one after the other. At this time, inner portion of the bolls were dried up the chamber of capsule may be easily separated, septa also shriveled, most of the waste cotton was dark in color, Pycinidia of the causal organism on the surface of the boll is shown in plate I, Fig-3, and Plate II, Fig-2.

5. Spore formation stage: In this stage the pycnidia have already matured. The pycnidia protrude out of the tissues of the bolls and the pycnospores are discharged. The bolls are brown to black in color, powdered and finally become charcoaled. In humid conditions, pycnospores which delayed on the surface of the boll may germinate. So that, in some conditions, the bolls looked like a grayish colored tumour. In this stage, inner portion of the bolls have already been dried up and at the same time, chamber of the capsule appears a fibriceous with black colored stripe. The waste cotton became red-brown or black in color (see Plate I, Fig—4; Plate II, Fig—3).

## B. Causal Organism

1. Morphology: The hyphae are at first hyaline and later become granular, septate with much branched, and olive to brown colored when mature. The diameter of the hyphae is differs with its age. In general, there are 2-5 $\mu$. Pycnidia formed on the bolls at dry rot stage. They occured in scattered positions and were embedded in host tissue becoming erumpent at maturity. They are carbonaceous, flask-shape with rostrum and ostiole at the free end, separated from each other, no stroma, brown-black in color, smooth surface, and measured 147.4-227.8 × 174.2-268.0 $\mu$, average 170.5 × 225.1 $\mu$ (see plate V, Fg.-1). The wall of pycnidia are formed by tissue which consists of polygonal with brown to brown black colored cells. Immature pycnospores are hyaline, granular, and one celled. Mature pycnospores are elliptical or oval-shaped and consists of two cells (see plate V, Fig.-2). They, samples collected from the field, measure 18.2-33.6 × 9.8-19.6 $\mu$, average 26.1 × 13.4$\mu$. It seems that most of pycnospores in pycnidia are hyaline and one cell. But they are two

cells with brown color after being discharged through the ostiolum. Because of this it seems evident that formation of septum and discoloration of the spore take place just before the pycnospores are discharged. But in humid conditions, most of the spores just discharged, in general, are hyaline and one cell. Pycnospores, under favorable conditions, produce 1-2 germ tubes. Most of the germ tubes appear at the polar end of the pycnospores, (see plate V, Fig.-2). Several works recorded that the causal organism exhibited the perfect stage, however, up to the present it has not yet been found in Taiwan by the writer. For comparing the findings of previous workers on the size of pycnospores with those of the writer, Table 1 is given as follows:

Table 1.-Measurement of Pycnospores of *Diplodia gossypina* by different workers

| Authorities | Pycnidia | Pycnospores | Hosts | Remarks |
|---|---|---|---|---|
| Stevens (1925) | | 20-27×10-15 μ | Cotton | From Cooke's specimen |
| Stevens (1926) | | 20-33×10-18 μ | Cotton | |
| Miyake (1938) | | 22×12 μ | Cotton | |
| Roger (1953) | | 17-35×9-23μ | Cotton | |
| Writer (1959) | 147.4-227.8×174.2-268.0 μ. | 18.2-33.6×9.8-19.6 μ | Cotton | |

2. Cultural characteristics: Culture of the causal organism provided in the investigation is isolated from diseased tissue and by using Ezekiel's method with single spore isolation. It is clear that symptoms obtained by inoculations with the organism isolated mentioned above are normal. Thus, it may confirm the isolates used in the investigations as being the correct pathogen of the disease.

a. Temperature in relation to the growth of the colonies:

In this experiment potato sucrose agar was used in order to determine the minimum, optimum and maximum temperatures for the growth of the causal organism. The effect of different temperatures on growth of the causal organism was determined by growing the causal organism in petri-dishes 90 mm. in diameter containing potato sucrose agar. Inocula were seeded in the central part with 5 mm. square of agar supporting actively growing mycelium. Cultures were grown at 10 different temperatures: 10°, 15°, 20°, 25°, 28°, 30°, 32°, 35°, 40°, and 45°C. Different temperatures were tested at the same time. The measurements of colonial diameter were taken every 12 hours along the diameter of colony at right angles. Cultural characters (Plate VI) were described 48 hours after incubation. The results given in Fig.-1 are the average of 5 replications.

Cultural Characters:

10°C: No growth took place.

15°C: Colonies flat, white, slightly translucent, entire edge, aerial mycelia almost visible.

20°C: Aerial mycelia poor.

25°C: Aerial mycelia cottony.

28°C: Aerial mycelia abundant in the part between center and margin of the colonies.

30°C: Aerial mycelia very abundant on all parts of the colonies.

32°C: Aerial mycelia abundant except at the center.

35°C: Ditto.

40°C: Aerial mycelia visible.

45°C: No visible growth was noticed.

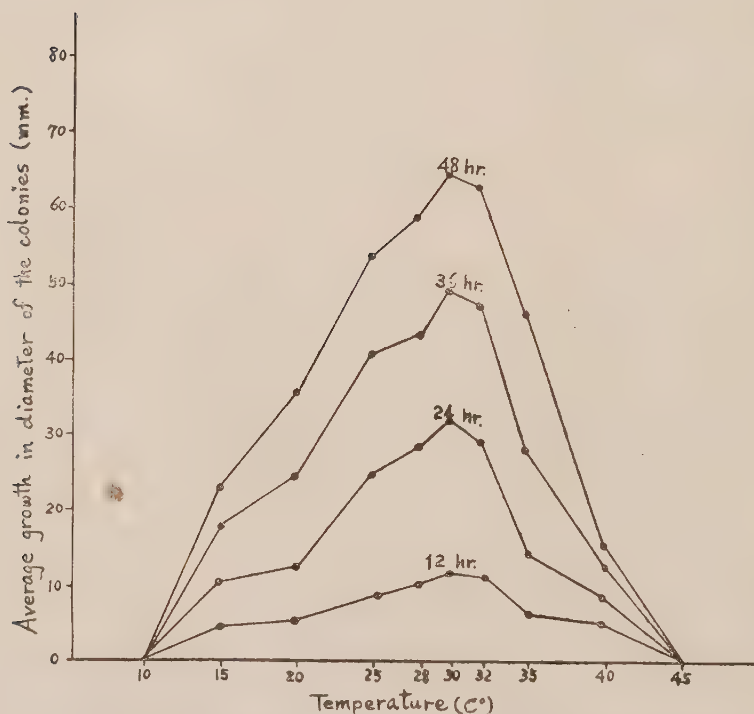



Fig. I.——Mycelial growth of ***D.gossypina*** on potato sucrose agar at different temperatures incubated for a period of 48 hours.

From the above data, it seems evident that temperature for growth of the causal organism covers a wide range. Measurements of colonial diameter examined showed mycelial growth occurred at 15~40° C, with an optimum 28–32° C; best growth occurred at 30°C, and at 10°C and 45°C no mycelia were visible, probably the minimum for the growth may be slightly higher than 10°C and the maximum temperature slightly lower than 45°C.

As to the development of aerial mycelium, it was clear that the causal orgaanism formed visible aerial mycelia at 15°C and 40°C, But at 25° to 35°C the aerial mycelia grew abundantly and readily (See Plate VI, Fig–1).

b. The effect of different media on growth of the colony:

In order to understand the characteristics of the causal organism growing on different media, 15 kinds of media were employed. They were Sabourand's medium, Czapek's solution agar, Elliott's agar, Richard's solution agar, Barne's medium, glucose agar and 9 kinds of plant tissue extract agar, such as, oat agar, corn agar, carrot agar, green bean agar, onion agar, lima bean agar, tomato agar, potato agar, and peanut agar. Tissue extract agar was made of 1000 ml. of distilled water, 20 gr. plant tissue, 20 gr. sand sugar, and 20 gr. agar. The results of this investigation are given in detail in Table 2.

Table 2.——Effect of different media on growth in diameter (mm.) of the colony of *D. gossypina*

| Media \ Period of incubations (hr.) | 12 | 24 | 36 | Order in comparative growth |
|---|---|---|---|---|
| Sabourand's medium | 16.5 | 30.0 | 54.4 | 13 |
| Czapek's solution agar | 18.1 | 35.1 | 64.0 | 8 |
| Elliottt's agar | 13.7 | 27.6 | 48.0 | 15 |
| Richard's solution agar | 17.4 | 36.4 | 71.3 | 5 |
| Barne's medium | 13.5 | 28.8 | 59.3 | 12 |
| Glucose agar | 17.9 | 36.5 | 63.5 | 9 |
| Oat agar | 16.8 | 31.1 | 52.5 | 14 |
| Corn agar | 18.4 | 34.7 | 59.4 | 11 |
| Carrot agar | 18.3 | 39.4 | 72.0 | 4 |
| Green bean agar | 17.8 | 36.7 | 67.3 | 7 |
| Onion agar | 18.4 | 37.5 | 69.5 | 6 |
| Lima bean agar | 17.8 | 35.0 | 61.9 | 10 |
| Tomato agar | 18.3 | 36.7 | 72.6 | 3 |
| Potato agar | 22.8 | 41.0 | 79.5 | 1 |
| Peanut agar | 23.9 | 43.9 | 75.6 | 2 |

As for growth in diameter of the colony, those of potato agar, carrot agar, peanut agar, green bean agar, onion agar, tomato agar, Richard's solution agar and Czapek's solution agar gave the best results, while Elliott's agar, oat agar, Sabourand's medium, Barne's agar, corn agar, and lima bean agar, gave the poorest results. As for degree of growth of aerial mycelium, those potato agar, peanut agar, carrot agar, onion agar, green

bean agar, tomato agar, glucose agar, and Sabourand's medium gave the best results. Beyond these, Czapek's solution agar, oat agar and corn agar, gave the worst results.

c. Nitrogen source in relation to growth of the causal organism:

The object of this experiment is to seek for the characteristics of the causal organism addicted to nitrogen source for growth. For accuracy Dox modification of Czapek's solution agar was used as basal medium, $NaNo_3$ contained in this medium taking the place of ammonium nitrate. Potassium nitrate, urea, ammonium chloride, and ammonium sulfate were used in different concentrations, molar concentrations of the chemicals used in this experiment ranged as 0.02 M, 0.06 M, 0.18 M and 0.54 M. Different chemicals of definite concentrations were added separately into basal medium in order to adjust the concentrations to those decided on beforehand. Each flask (100ml.) containing 20 ml. medium was seeded with 5 mm. square mycelial mats. Cultures were kept in incubator at 30° C. The growth of the causal organism was determined by weighting the mycelial oven dry weight on analytical balance 36 hrs. after incubation. The results of this experiment are shown in Fig. 2. It shows that mycelial growth was best in medium containing 0.02 M ammonium nitrate, and that on medium containing 0.18 M potassium nitrate followed in order, and growth was worst in urea even in its lowest concentration.

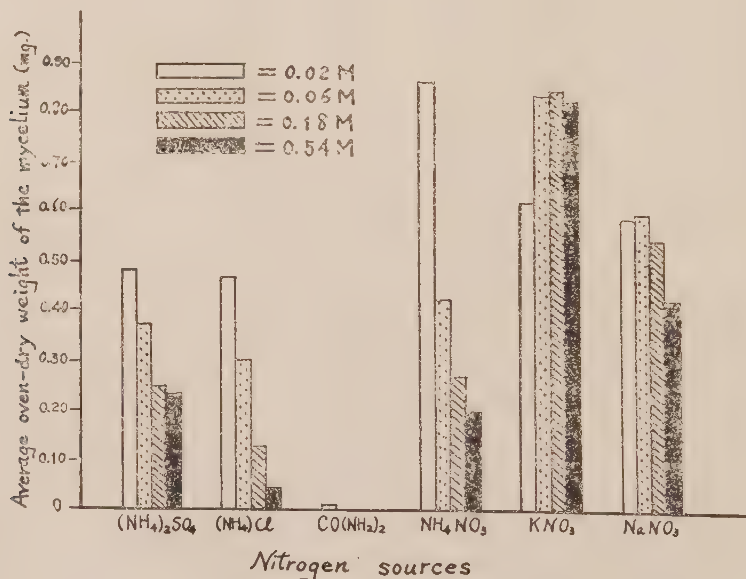



Fig. 2.——Nitrogen source in relation to growth of the causal oganism.

d. Carbon source in relation to growth of the causal orgaism:

Three kinds of saccharides, viz. glucose, sucrosc and soluble starch were provided in this experiment. The same method for determining the growth of the mycelia by the oven-dry weight mentioned in the test of nitrogen source was also employed in this expriment.

Glucose, sucrose and soluble starch were added to the medium in predetermined concentrations. The percentage method was employed to express the concentration, because of the molecular formula of the polysaccharide soluble starch is not clear and thus a definite gram molecular weight cannot be assigned to it. The percentage concentration employed, were 0.01%, 0.03%, 0.06% and 0.09%. Koch's method was employed to avoid decomposition of saccharides when sterilized in autoclave.The results of this experiment are given in detail in Table 3 which shows that concentration above 0.06% were used, mycelial growth was best in soluble starch, while glucose and sucrose gave poorer results. On the other hand, the growth of the mycelium, in concentrations of the chemicals below 0.06%, was best in sucrose, next best in glucose, and poorest in the soluble starch. The results of this experimeent demontrate that raising of concentration increases mycelium growth.

Table 3.——Average oven-dry weight (mg.) of mycelial mats of *D. gossypina* produced on different source of carbon 10 days after incubation

| Carbon sources \ Concentrations (%) | 0.01 | 0.03 | 0.06 | 0.09 |
|---|---|---|---|---|
| Glucose | 105.1 | 332.2 | 627.0 | 979.0 |
| Sucrose | 150.7 | 350.1 | 547.3 | 869.5 |
| Soluble starch | 97.3 | 321.2 | 658.5 | 1062.5 |

e. The effect of different H-ion concentration on growth of the causal organism:

In this experiment, Czapek's solution was employed as basal medium. Media of different H-ion concentrations were prepared by using HCl and NaOH with 0.1 N and 1.0 N solution ranged at pH 0.5 intervals from pH 2.0-10.5. To avoid the effect of poor illumination in preparation an injector was employed after sterilization to regulate the H-ion concentrations. In the experiment the oven-dry weight of mycelial growth was determined as mentioned in previous experiment. The results of this experiment are given in Fig. 3. It shows that growth of *D. gossypina* in different H-ion concentration ranging from pH 4.0-9.5. Optimum growth occured at pH 6.0.

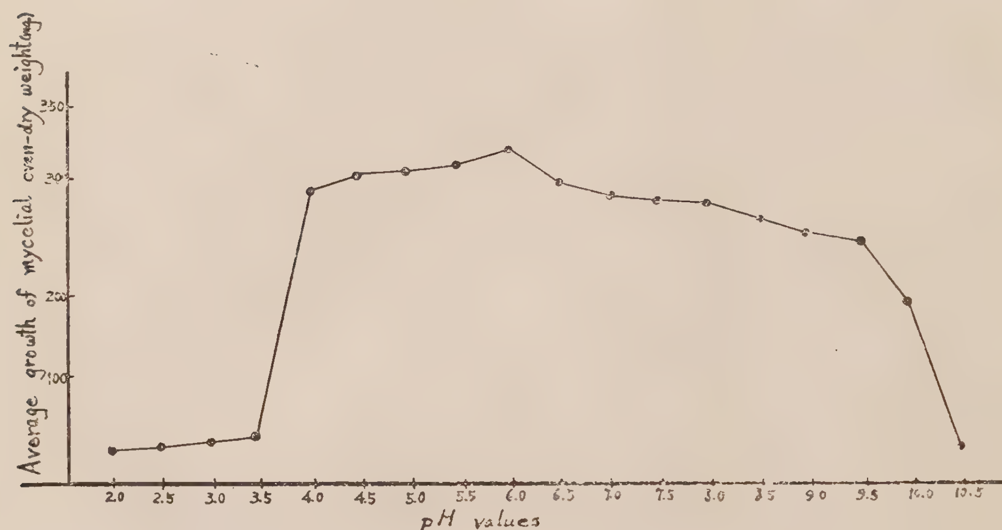



Fig. 3.——Comparative growth of mycelium oven-dry-weight of ***D. gossypina*** at different pH values on Czapek's solution 10 days after incubation.

f. Effect of temperatures on germination of pycnospores:

In the present study, pycnospores were subjected to various temperatures on microscopic slide suspended in petri dishes above 10 ml. of tap water. The slides were dropped with spore suspensions in paraffin wells (Spore suspensions were made by using actively germinating spores from cotton bolls collected from the field). The slides thus prepared were placed in incubators at various temperatures, and removed after different intervals over a period of 5 hours. The samples of pycnospores incubated were taken every hour, and germination percentages of each sample was determined. The effect of temperature on length of germ tubes of pycnospores was also studied. Spores were fixed with 10% formalin for immediate killing at different intervals of incubation. The results given in Fig. 4 and Fig. 5 were determined by averaging all germination percentages. The temperature range allowing germination was 15-40° C. The percentage of germination of pycnospores of *D. gossypina* was highest and the growth of germ tubes was most rapid at 30°C. The minimum temperature for germination was 15°C and the maximum near 40°C over 5 hours period; no spore germinated at temperatures below 10°C or above 45°C; most germination occurred between 25-35° C. The tests for measurement of the germ tubes gave the same results as those given in experiments showing effect of temperature.

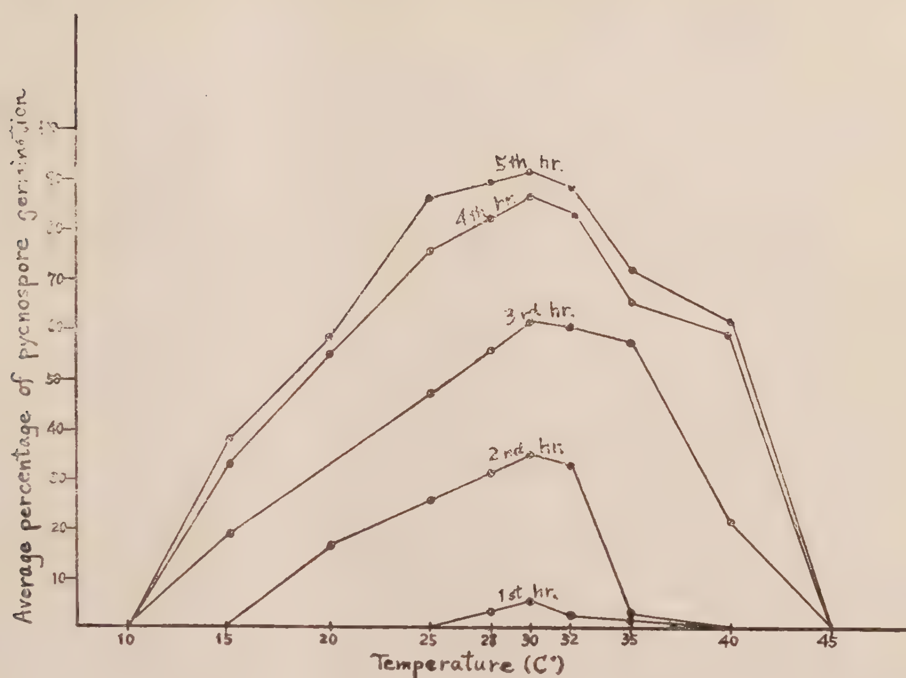



Fig. 4. Length of germ tubes of pycnospores of *D. gossypina* grown on microscopic slides at different temperature after different periods, each point on this graph through the 5 hours period is an average of 600 spores in 3 replications.

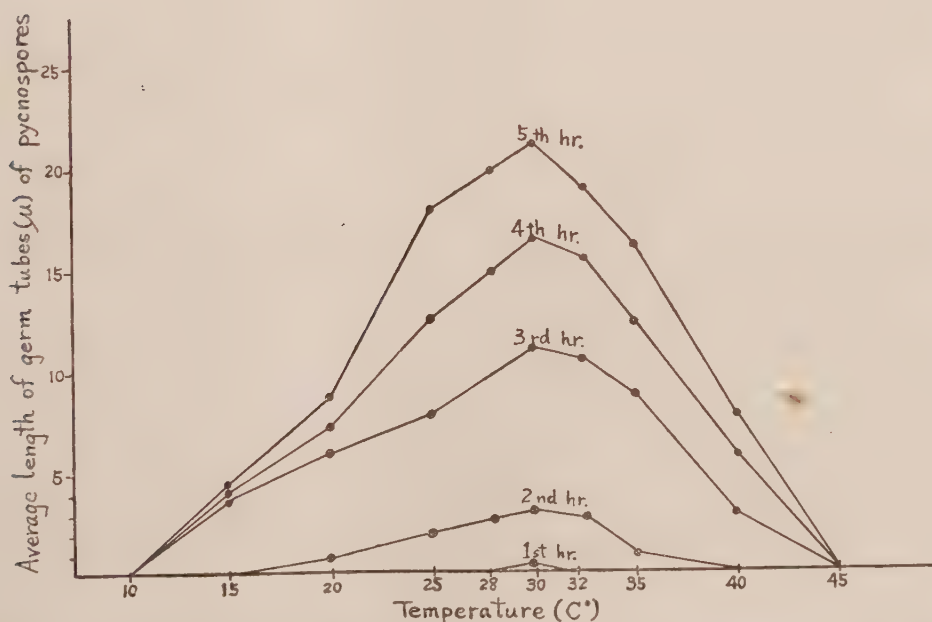



Fig. 5. Percentage of germination of pycnospores of D. *gossypina* on microscopic slides at different temperature after different periods. Each point on this graph through the 5 hours period is an average of 600 spores in 3 replications.

## C. Inoculation Experiments

Wound inoculations with mycelial mats were made on the surface of healthy cotton bolls. The bolls were placed in a moist chamber for 48 hours after inoculation, and then placed in a incubator at temperature of 30°C. The results of the tests showed that 10 days more or less are needed for the formation of pycnospores after inoculation. The symptoms obtained from this investigation are normal and are quite similar to those observed in the field upon appearance and progresisve change (see plate VII) of the disease. Observations on the evolution of various stages of the symptoms were made by the writer who found, in general, the lower the temperature the more dilatory the appearance of symptoms. On the other hand, the duration of the soft rot stage is longer on the bolls kept in the moist chamber for a longer period than those transferred from the moist chamber to the incubator before making the final reading. Thus it is evident that the duration of the soft rot stage is depends upon the moisture contained in the air. Inoculations on the unwounded bolls by using pycnopsore suspensions and mycelial mats were also made. No symptons appearred which indicated that the causal organism can only infect through wounds. According to Eddins (1930) report, the causal organism can attack the citrus fruits including grapefruit, sweet potatoes and watermelons, if they are artificially inoculated. Several inoculations made on tubers of sweet potatoes, peanut stems, cotton bolls, and fruits of the bananas, oranges, lemons, etc. were carried out by the writer. The results shown in Table 4 which indicated that the symptoms present on fruits of banana, lemon, mango, watermelon, apple, etc. are similar with those which appeared on cotton bolls and all of them unber go the soft rot stage before pycnospore formations. Among these, lemon fruit becomes carbonaceous (charcoal) at the late stage, It was apparent that mango fruits tend to increase their susceptibility to infection as they grow older on maturation.

The writer made inoculations on cotton bolls, peanut stems and jute stems for comparision of the susceptibility with three isolates, ***Diplodia gossypina, D. arachidis*** and ***D. corchori***. The results are given in detail in Table 5 and show that three isolates mentioned above differ from each other in susceptibility.

Although pycnidia formed on cuture of plant tissues are much more abundant than those formed on artificial media. However, in favorable conditions if artificial inoculation had taken place in a room, pycnidia formation through 4 to 11 days on cotton bolls is better than that on culture of plant tissues. It appears that pycnospores, in general, may protrude 6 to 15 days after inoculation. It is observed that ventilation is very necessary to the causal organism's sporulation.

Table 4.——Results of inoculation with *D. gossypina* on different materials seven days after inoculation

| Materials | Parts or Position | wounded or unwounded | No. | Diseased No. | Incubation period | Remarks |
|---|---|---|---|---|---|---|
| Banana | rachis of the fruits | wounded | 6 | 6 | 3 | Soft rot in brown color |
| 〃 | Fruit | wounded | 6 | 6 | 4 | 〃 |
| 〃 | 〃 | unwounded | 6 | 2 | 4 | 〃 |
| Apple | 〃 | wounded | 2 | 2 | 2 | 〃 |
| 〃 | 〃 | unwounded | 3 | 0 | — | 〃 |
| Orange (poonkan) | 〃 (coat) | woundeded | 3 | 3 | 3 | 〃 |
| 〃 | 〃 | unwounded | 6 | 0 | — | |
| 〃 | stem-end | 〃 | 3 | 0 | — | |
| Onion | bulb | wounded | 6 | 0 | — | |
| 〃 | 〃 | unwounded | 6 | 0 | — | |
| Water melon | fruit | wounded | 6 | 5 | 3 | One of them become soft rot caused by *Fusarium sp.* |
| Lemon | stem-end | wounded | 6 | 5 | 4 | Soft rotund then become Carbonaceous (charcoal) |
| | coat of the fruit | unwounded | 6 | 0 | — | |
| Sweet potato | root | wounded | 6 | 4 | 4 | The symptom is w eak |
| | 〃 | unwounded | 6 | 0 | — | |
| Corn | stem with leaf sheath | wounded | 6 | 6 | 3 | The plant died at the final stage |
| | 〃 | unwounded | 6 | 6 | 3 | 〃 |
| Peanut | stem | wounded | 6 | 6 | 4 | 〃 |
| Soybean | 〃 | wounded | 6 | 4 | 5 | The symptom is not clear |
| | 〃 | unwounded | 6 | 0 | — | |
| Jute | 〃 | wounded | 3 | 3 | 4 | Defoliation |
| | 〃 | unwounded | 3 | 3 | 4 | 〃 |
| Mango | fruit | wounded | 6 | 6 | 6 | Soft rot |
| | 〃 | unwounded | 6 | 6 | 7 | 〃 |
| | stem | wounded | 6 | 0 | — | |
| | 〃 | unwounded | 6 | 0 | — | |

Table 5.——Comparative inoculation on determine the susceptibtility of three isolates of *Diplodia* on different host

| Isolates \ Materials | Cotton bolls | Peanut stem | Jute stem |
|---|---|---|---|
| *D. gossypina* | ++ | ++ | ++ |
| *D. arachidis* | +++ | +++ | ++ |
| *D. Corchori* | + | + | +++ |

Note on susceptibility : + = weak, ++ = medium, +++ = strong.

## D. Chemical effects on the pathogen in vitro

To select the effective fungicides in conjunction with the field experiment, tests were made to determine the relative toxicity of the fungicides. In this investigation, the glass slides method for pycnospore germination was used. The glass slide used in this test is prepared as the same as mentioned in the section of pycnospore germination.

18 fungicides were employed, they were Perenox, King Mercuric Bordeaux, Hokko Mercuric Bordeaux, Hokko Ruberon Tablet, Riogen, Yamamoto Micron Emulsion, New Improved Granosan, Agrrosan, Ceresan, Fumiron Tablet, Orthocide-75, Dithane M-22, Dithane Z-78, Dithane S-31, Zerlate, Phygon-XL, Tuzet, and Fermate. All the fungicides mentioned above were regulated into different concentrations, 50 p.p.m. 125 p.p.m., 250 p.p.m., 500 p.p.m., and 1000 p.p.m.. Pycnospore suspensions were made by washing active pycnospores formed on the bolls which were collected from the field. Pycnspore suspensions were adjusted to a concentration of 25 spores in each of the microscopic field. Before fungicidal test, a given volume of spore suspension and the same volume of various fungides with their different concentrations were mixd together in order to regulate the fungicides in the spore suspension to the desired concetrations, 100 p.p.m., 250 p.p.m., 500 p.p.m., 1000 pp.m., and 2000 p.p.m.. Three uniform drops of spore suspension thus prepared were place on each slide mentioned before. The glass slides were then placed in petri dishes moist chamber and were kept in room at the temperature 30° C for a period of 5 hours before final examination was made. Percentage of pycnospore germination was determined with microscope after each hour. Of 400 spores were counted from each of three drops and averaged for the percentage spore inhibition. The results, given in detail in Table 6, are the average of three replications. According to the data presented in Table 6 it is apparent that all the fungicides tested which gave a positive result in inhibition of the pycnospores at the level of LD 50 in comparison with untreated spores (check). From the point of view of the effectiveness of various fungicides

in varying concentrations giving different results under the level of the concentration 500 p.p.m., the middle concentration, those of Zerlate, Ceresan, Hokko Ruberon Tablet, Phygon-XL, and Fermate gave better results than others in inhibiting germination of the pycnospores.

The results obtained from this investigation show that most of the fungicides, in general, possess good power of inhibiting the pycnospore germination after one to four days of germination. However those fungicides with superior toxicity affect have good power of inhibiting pycnospore germination even after 5 hours incubation. For this reason the results obtained have special significance and are recorded here.

Table 6.——Toxicity effect of 18 fungicides in inhibiting the percentage germination of the pycnospores of *D. gossypina* after five hours incubation

| Fungicides \ Concentration (p.p.m.) | 100 | 250 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|
| Perenox | 90.58 | 98.77 | 98.85 | 99.43 | 100.00* |
| King Mercuric Bordeaux | 93.76 | 95.08 | 99.42 | 100.00* | 100.00* |
| Hokko Mercuric Bordeaux | 92.61 | 95.66 | 99.42 | 99.83 | 100.00* |
| Hokko Ruberon Tablet | 97.11 | 98.85 | 100.00* | 100.00* | 100.00* |
| Riogen | 68.85 | 94.79 | 96.09 | 100.00* | 100.00* |
| Yamamoto Micron Emulsion | 98.99 | 99.28 | 99.57 | 100.00* | 100.00* |
| New Improved Granosan | 97.93 | 98.85 | 98.99 | 99.42 | 99.57 |
| Agrosan | 97.69 | 98.12 | 98.99 | 99.64 | 100.00* |
| Ceresan | 97.40 | 98.85 | 100.00* | 100.00* | 100.00* |
| Fumiron Tablet | 93.34 | 96.38 | 99.28 | 100.00* | 100.00* |
| Orthocide-75 | 94.74 | 98.00 | 99.43 | 100.00* | 100.00* |
| Dithane M-22 | 96.67 | 97.47 | 99.72 | 100.00* | 100.00* |
| Dithane Z-78 | 85.34 | 92.32 | 93.92 | 98.56 | 100.00* |
| Dithane S-31 | 57.73 | 89.50 | 97.11 | 99.83 | 100.00* |
| Zerlate | 97.98 | 99.42 | 100.00* | 100.00* | 100.00* |
| Phygon-XL | 97.83 | 99.42 | 100.00* | 100.00* | 100.00* |
| Tuzet | 99.18 | 99.42 | 99.72 | 100.00* | 100.00* |
| Fermate | 88.63 | 99.45 | 100.00* | 100.00* | 100.00* |
| Check | 0 | | | | |

Note: * = Showing greatest effectiveness in inhibition of pycnospore germination.

## V. DISCUSSION

Soveral diseases caused by *Diplodia* were recorded in Taiwan (14) They are stem-end rot of orange (*Diplodia natalensis*), Boll black rot of cotton (*D. gossypina*), Java black rot of sweet Potato (*D. tubericola*), Black rot of agave (*D. fici-retusae*), Stem rot of castor bean (*D. recinella*), Twig blight of mulberry (*D. morina*). Several new diseases caused by *Diplodia* were found in this island by the writer, they are Stem blight of jute (*D. corchori*), Stem rot of peanut (*D. arachidis*), and avocado charcole rot (*Diplodia sp.*) According to observations under microscopic examination carried out by the writer, it seemed likely that 7 species of *Diplopia* mentioned above resemble each other in their morphological character, such as *D. natalensis*, *D. gossypina*, *D. arachidis*, *D. corchori*, and *Diplodia sp.* on avocado (12,22). Stevens (1925-1926) reported *D. gossypina* is indistinguishable from *D. natalensis*. The perfect stae of *D. gossypina* was named by Stevens as *Physalospora gossypina* which depends upon the morphology of the perfect stage. Later in another report, he concluded that the perfect stage of the fungus which has usually been called *D. natalensis* in U. S. A. is apparently identical with *Physalospora rhodina* (Berk. & Curt.) Cooke. *Physalospora gossypina* as used in papers is apparently a synonym of *P. Rhodina* (7, 23, 24, 26). Eddins (1930) reported that the causal fungus is indistinguishable from *D. frumenti*, *D. natalensis* and *D. tubericola* in their imperfect stage and cultural characteristics (6). The results of studies on cultural characteristics investigated by writer showed that the temperature range for growth of the organism is wider. Mycelium grows well in the temperature range 15-40°C, 10°C is the minimum temperature for the growth of mycelium, and 40°C is the maximum temperature for growth of the mycelium. and 28°-32°C, especially at 30°C, is the optimum temperature for mycelium growth and for germination of pycnospores. There is no doubt that the causal organism belongs to the genus *Diplodia* of low temperature form (24). But up to the present, the writer has not yet found the perfect stage of the causal organism in Taiwan, and a study should be made the causal organism is identical or not with those named above.

The temperature in cotton growing localities of Taiwan is approximately coincides with the temperature for growth of the causal organism and its reproduction. On the other hand, the incubation period of the disease, under the favorable conditions, is short and 2 days is long enough for the appearance of symptoms to occur. There is no doubt that a number unavoidable conitions such as humidity and temperature are closely related to the virulence of the disease. According to field observations, it seems that the occurrence of the disease is closely connected with the times and a certain quantity of rainfall. The humid weather, in fact, may help to spread of the disease in the fields. The result of tests of inoculations indicate that the causal fungus can only infect through wounds. There are many insects pests, especially the pink bollworm which produce

injuries leading to the occurrence of black rot (2). From this it is evident that control of insects may provide the best effective control of the disease.

## VI. SUMMARY

Boll black rot, caused by ***Diplodia gossypina.*** is one of the most prevalent and damaging disease of cotton in many of the cotton-growing regions of Taiwan. The first symptom of infection by the black rot fungus in the appearance of a slightly greenish spot on the surface of the fruit or boll. Later, the spot enlarges and becomes more pronounced. The tissue, however, is killed and turns brown to brown-black and rapidly involves the entire surface of the boll. Thus, the bolls are killed by the causal fungus, and finally become dry and carbonaceous. In addition to the fruits, such as the petioles, stems and fruit-stems also may be attacked severely. During the late stage of the disease, the fungus produces conspicuous pycnidia on the surface of the diseased parts. A great number of pycnospores, under favorable conditions, are discharged from them. The pycnospores are transmitted by insects, wind, etc. Rain after germination splash the spores to surrounding plants, and eventually many of the healthy fruits in the field may become infected.

The writer wishes to point out that according to the microscopic examinations the morphology of the causal fungus is indistinguishable to the stem rot fungus ***D. arachidia*** on peanut, stem end rot fungus ***D. natalensis*** on citrus fruits, and black rot fungus ***D. tubericola*** on sweet potatoes which commonly occur in Taiwan. In fact, however, the morphology of the causal fungus denoted by the writer in the present paper is closely identical with Cooke's, Stevens and other reports of cotton boll black rot fungus ***Diplodia gossypina.*** The abundant pycnidia of the causal fungus appear sporadic or scattered on the surface of diseased fruit of the cotton. They are half immersed in tissue of the host, and are brown to brown-black in color and carbonaceous (Charcoel) and measure $147.2–227.8 \times 174.2–268.0\,\mu$.. Immature pycnospores are granular, one-celled and hyaline, like those of the form of the genus ***Macrophoma.*** When mature, they become dark-brown and two-celled, measure $18.2–33.6 \times 9.8–19.6\,\mu$., average $26.114 \times 13.400\,\mu$. and agree very well in form with Cooke's description of pycnspores of cotton boll black rot ***Diplodia*** found in Bombay (India) in 1879. Up to the present, however, the writer has not found in microscopic examinations any specimen which contained the perfect stage of the causal fungus.

The exact conditions leading to the development of the black rot are not clear, but it seems possible that a continuous rainfall or humid weather conditions in the growing season, according to the field observations, is the best factor for the development of the disease.

The results of the tests on temperature for growth of the causal organism in culture and pycnospore germination showed that the minimum temperature is 10°C, the optimum temperature is 30° C, and the maximum temperature is 40° C.

As for growth in diameter of the causal organism, those of potato agar, peanut agar gave the best results, while Elliott's agar, Sabourand's medium and oat agar gave the worst.

The results of the tests of nitrogen source in relation to the growth of the causal organism which showed that mycelial growth was best in medium containing. Carbon source in relation to the growth of the causal organism which showed that mycelial growth is best in soluble starch under the concentration 0.09%. Glucose and sucrose follow in order.

In other hand, growth of the causal organism in different H-ion concentration ranging from pH 4.0-9.2, optimum growth occurred at pH 6.0.

Studies indicated that Zerlate, Hokko Ruberon Tablet, Ceresan and Fermate gave effective results in inhibiting germination of the pycnospores.

From the results of inoculation tests it is clear that plants can be infected by the causal fungus only through a wound, thus, the damage due to insects, anthracnose disease caused by ***Glomerella gossypii*** or diseases caused by other pathogens and the mechanical injuries are the best ways for infection by the causal fungus.

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## VIII. PLATES

### Plate I :



Fig.——1. Symptom of primary infection stage.



Fig.——2. Symptom of soft rot stage.



Fig. 3. Symptom of dry rot stage.



Fig. 4 Symptom of spore formation stage.

Plate II :



Fig.——1. Symptom of soft rot stage, inner view.



Fig.——2. Symptom of dry rot stage, inner view.



Fig.——3. Symptom of spoie formation stage, inner view.

Plate III :



Fig.——1. Symptom showing the infection in the apex of the boll.



Fig.——2. Symptom showing the causal organism attack on the suture of the boll.

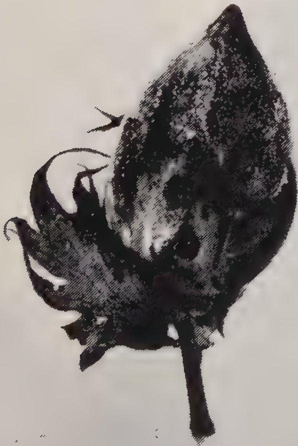


Fig.——3. Symptom showing the causal organism attack through the hole made by pink worm.



Fig.——4. Symptom showing appearance of abundant mycelium on the boll at humid conditions.

Plate IV :



Fig.—1. Late stage of the symptom, showing charcoal rot, inner View.



Fig.—2. Diseased boll (left) and healthy boll (right).



Fig.—3. Diseased boll (left) and healthy boll (right) in mature stage.

Plate V :

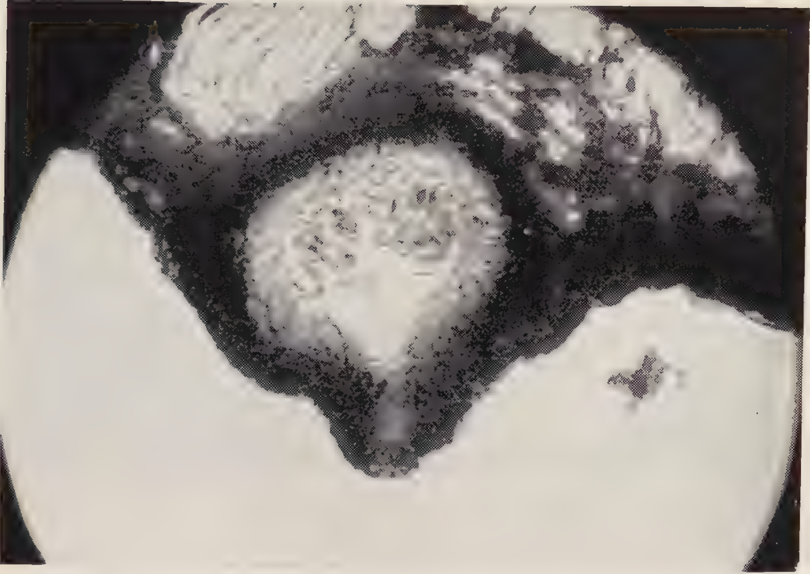


Fig.—1. Pycnidia of the causal organism, cross view.



Fig.—2. Pycnospores showing germination.

Plate VI :

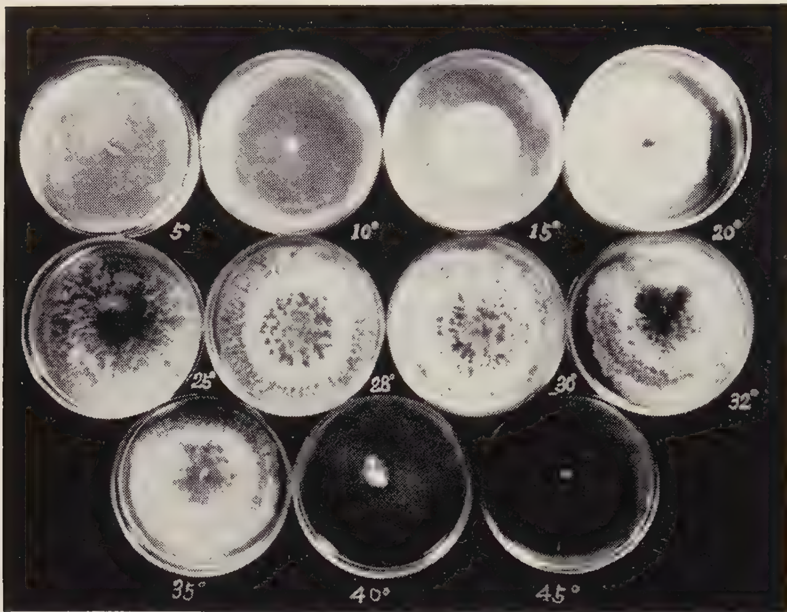



Fig. — 1. Temperature (C°) in relation to the growth of colonies of *D. gossypina*.

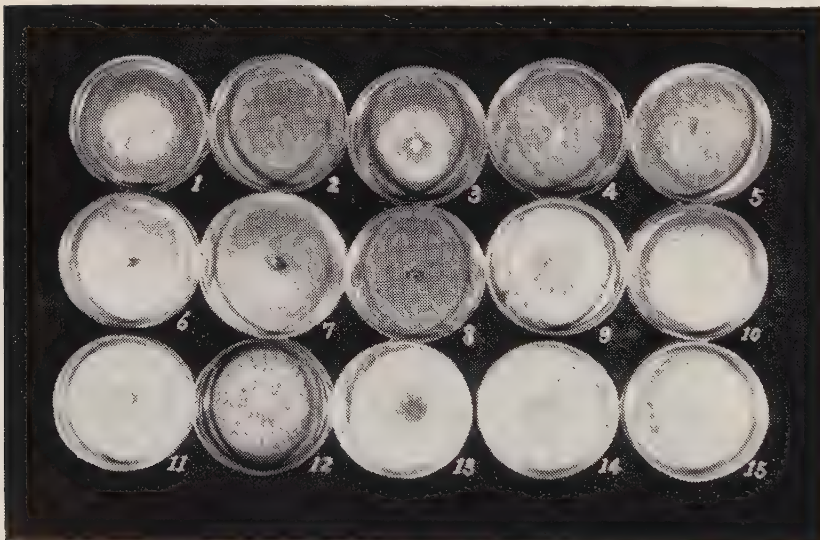



Fig.——2. Different media in relation to the growth of colonies of *D. gossypina*. 1=Sabourand's medium, 2=Czapek's solution agar, 3=Elliott's agar, 4=Richard's solution agar, 5=Brane's medium, 6=cgucose agar, 7=oat agar, 8=corn agar, 9=carrot agar, 10=green bean agar, 11=onion agar, 12=lima bean agar, 13=tomato agar, 14=potato agar, 15=Peanut agar.

## Plate VII :



Fig. --1. Symptom on the cotton boll obtained from artificial inoculation, after 48hr. 72hr. 108hr. and 140hr. (from left to right).



Fig. —2 Symptom on the cotton boll obtained from artificial inoculation, inner view.

# 台灣經濟植物 Diplodia 病害之研究

# 1. 棉鈴黑腐病

羅　清　澤

臺灣自光復以來，政府爲發展紡織事業，以減少外滙之消耗計，故對於纖維作物種植面積之推廣，栽培技術與品種之改良，以及對病蟲害防治對策之探求，不遺餘力，數年來收效頗著。如民國45年棉花之栽培面積爲1,933.00公頃，總產量爲780,9?2.00公斤；至48年栽培面積增至9,363.00公頃，總產量4,427,339公斤。據台灣棉作總報告(1959)，台灣每年所需短絨棉(子棉)7,500萬磅，長絨棉500萬磅，此數若與該期之總產量400餘萬磅相較，則不足之數尙在7,000餘萬磅，故每年所需外滙達1,700萬至2,000萬美元左右，以仰給國外輸入(ba)。台灣紡織事業，日益發達，除供給國內之需要外，尙因品質之逐漸改進，而亦大量輸出換取外滙，對於國計民生，裨益良多。然爲百尺竿頭，再進一步計，對於種植之面積，及單位面積之產量與品質，應積極研究改進。

據田間調查所知，台灣棉作地區之病害發生至爲嚴重，每因猖獗爲患，以致產量與品質損失極鉅；就中以棉鈴黑腐病(Boll black rot)爲害最甚，筆者有鑑及此，乃於民國四十九年始着手研究，茲將所獲結果整理成篇，期能拋磚引玉，以導致對棉作病害之注意研究，俾能使質與量之提高，並可減少外滙之消耗。

棉鈴黑腐病爲Cooke(1879)首先發現於印度之孟買(Bamby)，並將引起此病之病原菌命名爲Diplodia gossypina Cooke，至今仍在沿用中。1912年 Edgerton 報告美國 Louisiana 州種植之棉花，因本病猖獗爲患，損失至鉅。而於 1924 年，美國中部及東部諸州之棉作區域在8月下旬以前後，本病發生甚劇，以致產量減收30-40%以上。Cooke (1925)復報告Poerto Rico之棉花因 Diplodia gossypina 之爲害而致落鈴者達20%以上。Tucker (1925) 亦報告 Poerto Rico有棉鈴黑腐敗病之發生。Toro (1926) 報告 Poerto Rico 近海岸地帶之棉花由於 D. gossypina 之侵害引起大量之落鈴現象，氏並認爲在棉之開花期及結果期，土壤濕度過高時，乃落鈴主要原因之一。Stevens (1926) 報告 Physalospora rhodina 爲 Diplodia natalensis 及 D. gossypina 之完全世代。Wallace (1928) 報告，在1926年發現 Tanganyika 之 Shinyangan 地區內棉鈴上有 D. gossypina 之寄生。

Diplodia屬菌在台灣所引起之病害，除棉鈴黑敗病外，尙有柑桔蒂腐病 (D. natalensis) 甘藷炭化病 (D. tubericola)，花生莖腐病 (D. arachidis)，龍舌蘭屬之 Ayaves Sisalana 黑枯病 (D. agaves)，榕樹枝枯病 (D. fici-retusae)，蓖麻莖枯病 (D. ricinella Sawada sp. Nov.) 黃麻莖枯病 (D. corchori) 及桑樹 (Morus alba) 與 M. multic awlia 枝枯病 (D. morina) 等。就病原菌之形態言，本病原菌 (D. gossypina) 與前三種殆不易區別。據 Stevens (1925-1926) 報告，本病原菌 (D. gossypina) 與 D. natalensis 無法區別，氏並就本病菌之完全世代命名爲 Physalospora gossypina，此後氏又認爲本菌與 D. natalensis 之完全世代 Physalospora rhodina (Berk, and Curt.) Cooke 相同，故謂此二者爲同種異名。又據 Eddins (1930) 報告，本病原菌之不完全世代與 D. frumenti, D. natalensis 及 D. tubericola 均無法區別，其培養

性質亦復相同。筆者對本病原菌之培養結果，其菌落生長之溫度範圍甚廣，自 15°-40°C均能生長，最低爲 15°C，最高爲 40°C，其菌絲生長之最適溫度爲 30°C，而亦柄孢子發芽之最適溫度。Stevens 謂本菌係 Diplodia 屬中之低溫型者，pH 範圍爲 2.0-10.5，最適 pH 爲 6.0。至於本菌與前述諸菌是否爲同種異名，倘在比較研究中，容待另文報告之。

台灣地處亞熱帶，各地棉作期之氣溫與本病原菌之生育溫度幾近一致，此乃本病易於猖獗之主要原因。據田間觀察，本病與降雨次數之多寡具有密切關係，潮濕氣候可助長本病之蔓延。依接種試驗之結果，獲悉本病原菌多藉傷痍侵入，接種後如環境適宜，其潛伏期極短，僅需一至二日即顯現病徵。就病徵之演進過程，可分爲感染初期，濕腐期，濕腐末期，乾腐期及胞子形成期，最終使棉鈴炭化，而內部之棉絮變爲赤褐色或黑色腐敗。

本病原菌 (Diplodia gossypina Cooke) 之初生菌絲無色，而後經橄欖色變爲褐色，於棉鈴之乾腐期發生柄子器 (Pycnidia)，成熟時突出棉鈴表皮，呈橢圓形或圓形，大小平均爲 170.5 ×22.51 μ，黑褐色，表面光滑，頂端短嘴具有胞子散出孔(Ostiole)。柄胞子 (Pycnospore)呈卵圓形或橢圓形，成熟時爲褐色，具一隔膜，大小平均爲 26.1×13.4 μ。其發育之最適溫度爲30°C，最低爲 10°C，最高 45°C。菌絲發育之優劣，氮素源者，以硝酸鈉爲最優，碳素源者，則以0.06%之蔗糖爲最佳(見表一)。其胞子於培養基上不易形成，但在接種之棉鈴上，於 30°C 之溫度下歷時十天左右即有柄子器形成。

本病原菌，多藉蟲喰傷口或機械傷口爲其侵入之途徑。人工傷痍接種，於 30°C 左右之溫室內，經48小時即顯現典型之病徵。其寄主範圍，除棉花外，經接種於香蕉、蘋果、椪柑、西瓜、檸檬等果實，甘藷塊莖，洋葱鱗莖，玉蜀黍，花生及黃麻莖部等，除洋葱外，均先後發病。其對藥劑之反應，經室內試驗，於供試二十九種藥劑中，以500 PPM之 Eerlate，Ceresan，Hokko Ruberon, Phygonxl 及 Fermate 等五種對孢子發芽之抑制率 (LD50) 爲最優。至田間藥劑防治試驗，擬參照此項結果進行之。

# 水稻線虫心枯病之研究*

# STUDIES ON WHITE TIP DISEASE OF RICE

陳　脉　紀

Moh-jih Chen

## 一、緒　　言

民國四十八年十月間，著者曾於草屯及潭子一帶普遍發現水稻線虫心枯病之發生，其被害情形，係隨地區及水稻品種而有顯著差異，尤因品種之不同，其被害程度亦相差甚鉅。

據美國 Atkins 及 Todd 兩氏 (1959) (1) 之報告，將在研究室內培養之病原線虫，用於田間行人工接種後，可使最易感染之品種減收達 40～50% 以上，而感染性品種之減收率爲 17% (三年平均)，至於抵抗性品種之減收率亦有 7% 以上。

又據高雄區農林改良場洪元平氏 (1959) (12) 之調查，本病害在屏東，新竹及臺北等地之發生情形亦頗普遍。就品種言，以嘉農 242 號，臺北 13 號，高雄 10 號及高雄 64 號等最易感染，其發生率在 28～36% 之間，減收率則達 30～47%。

本病對水稻產量之影響已如上述，惟過去臺灣有關本病之專題報告尙付缺如，本試驗之目的在探究有關本病之病徵，病原線虫之形態，生態，生理性質以及種子處理等，俾供防治之參考。

## 二、前 人 研 究

1915 年，角田氏 (14) 首先報告本病 (當時稱爲黑粒病) 係由線虫 (Tylenchus sp.) 所引起。1916 年中野氏 (13) 報告粟之不稔病亦由線虫所引起，且與水稻黑粒病之病原線虫極爲相似。Tullis 及 Cralley 兩氏 (1936) (6) 報告本病係因缺鐵 (Iron deficiency) 所致。此後 Martin 及 Altstatt 兩氏 (1940) (5) 則認爲係因缺鎂 (Magnesium deficiency) 所引起。1941 年，田中及內田兩氏 (17) 報告，於日本北海道十數年來一直被認爲生理異常之一種水稻病害實係由一種線虫 (Anguillulina sp.) 爲害所致，並與角田氏報告者極爲相似。瀧元氏 (1943) (15) 則認爲本病係起因於水分不足之生理病態。1944 年，吉井氏 (21) 觀察本病，並解剖罹病植物，發現有病原線虫在水稻之生長點附近外部寄生，而於孕穗期有部份線虫侵入穎內，與穎之內側面相接觸，並命名本病爲水稻線虫心枯病。1948 年，横尾氏 (19) 鑑定吉井氏之線虫，而命名爲 Aphelenchoides oryzae Yokoo，並比較上述角田，瀧元、吉井、田中及內田諸氏之報告，認爲同一種。1949 年，山本及吉井兩氏 (18) 觀察粟之不稔病而認爲其病原線虫爲 A. oryzae。Cralley 氏 (3) (20) 於 1947 年訪問日本觀察水稻線虫心枯病與在美國一直被認爲缺鎂症之 White tip disease 極爲相似，氏回國研究後報告本病 (White tip) 確爲線虫爲害所致，並經 Allen 氏鑑定其病原線虫與 Aphelenchoides oryzae 爲同一種，1952 年，Allen 氏 (20) 比較檢討所謂 Bud and Leaf Nematodes 之 Aphelenchoides 屬線虫，則認爲 Aphelenchoides oryzae 與 1942 年 Christie 氏所發表之草莓 Summer dwarf disease 之病原線虫 Aphelenchoides besseyi 爲同一種。

*本著作之完成得國家長期發展科學委員會之補助，特此謹致謝忱。

## 三、病　　徵

本病之病徵在水稻生育初期多不顯明，惟罹病種子播種後，其發芽率較低，苗之長度亦較健全苗爲短。其典型病徵出現於分蘖旺盛期。被害稻株之葉尖，每於其抽出之當初即變呈白色透明狀或呈油浸狀黃色乃至黃白色，變色部之長度約爲 3-6cm。英名"White tip"則基於上述初期之病徵而得名 (6)。又因此期之油浸狀光澤，能在微風吹蕩時反射光線，宛似螢光，故俗稱爲"螢稻熱病" (16) (21)。罹病部與健全部之交界處呈暗褐色，微帶波狀，其外緣常以黃色暈帶包圍之。至後期，被害部漸次乾枯萎縮，亦有起捻轉或捲縮者（第一圖版，A），此種情形，尤以止葉爲甚。被害止葉一般較健全者顯著短縮，僅達 6-15cm（約爲健全止葉之 1/3 長)。被害葉片之寬度變狹其下部之健全部份，綠色加深，以致被害部益加明顯。罹病株之生育，一般較爲緩慢，但分蘖數增多。

被害穗顯著變爲短少，一穗中之枝梗數及粒數亦均減少（表二），且多不登熟而呈暗褐色乾枯狀（第一圖版，C），影響產量及米質至鉅。被害穗通常直立不下垂，其症狀嚴重者，常致抽穗發生困難，而迫使被害株引起生理之變態，由其上節另生 1～2 小穗（第一圖版，B）。

## 四、被　害　調　查

### I. 發病率調查

本調查於民國四十八年十月水稻抽穗期，分別在草屯及潭子兩地舉行之。調查方法係每品種隨機採樣 100 株，調查其每株之有效分蘖數及被害穗數，而後求其發病率。其調查結果如下表：

表一：　水稻線虫心枯病品種間發病率比較

Tabe I. Varietal susceptibility of rice plants to white tip disease

| 品種＼地區＼發病率(%) | 草　屯 | 潭　子 | 平　均 |
|---|---|---|---|
| 臺　中　65　號 | 6.4 | 37.6 | 22.0 |
| 臺　中　150　號 | 13.3 | 14.0 | 13.7 |
| 臺　中　170　號 | 18.0 | | 18,0 |
| 臺　中　180　號 | 10.0 | | 10.0 |
| 嘉　農　242　號 | 13.7 | 19.0 | 16.4 |
| 臺中糯　34　號 | | 57.3 | 57.3 |

由上表可知，本病之發病率因水稻品種及地區而有顯著差異，其中以臺中糯 34 號最易感染，其發生率竟達 57.3%。其次爲臺中 65 號，其兩地之平均發病率爲 22%，惟該品種在潭子之發病率則多達 37% 以上，此或因隣接該區之臺中糯 34 號之影響，以致病原線虫之密度增高之故。再次乃以臺中 170號，嘉農 242號，臺中 155 號及臺中 180 號爲序，其發病率均在 10% 以上。

### II. 減損率調查

本調查系就嘉農 242 號比較健全穗與被害穗之穗長，支梗數，穗種，粒數及千粒重等，以計算其減損率如下（除千粒重外，均爲 100 穗平均值）：

表二：　水稻線虫心枯病減損率調查

Table II. Effect of white tip of rice on yield of Chia-nung 242 variety

| 穗　長（cm/穗） | | | 支梗數（支/穗） | | | 粒　數（粒/穗） | | |
|---|---|---|---|---|---|---|---|---|
| 健全穗 | 被害穗 | 減損率（%） | 健全穗 | 被害穗 | 減損率（%） | 健全穗 | 被害穗 | 減損率（%） |
| 22.5 | 18.2 | 19.1 | 11.5 | 8.6 | 5.2 | 153.0 | 98.2 | 35.8 |

| 穗　重（gr/穗） | | | 千粒重（gr） | | |
|---|---|---|---|---|---|
| 健全穗 | 被害穗 | 減損率（%） | 健全穗 | 被害穗 | 減損率（%） |
| 4.5 | 2.0 | 56.4 | 31.9 | 11.5 | 63.9 |

如上表所示，如就穗重與千粒重二項比較健全穗與被害穗之減損率，則前者減損 56.4%，後者減損達 63.9%。至於穗長，支梗數及粒數等，雖其減損之程度不如前二項之高，惟被害穗多含不稔粒，以致影響重量之顯著減低。

## 五、病原線虫

### I. 形　　態

虫體細長，體表由角質層所包圍，並密佈橫條溝 (Trsnsverse striations) 。頭部凸出，易與體部劃分。口唇 (Lips) 各片癒合而呈凸出狀。口針 (Buccal spear) 堅强，具有節球 (Basal knobs) 。中部食道球 (Median oesophageal bulb) 明顯而發達，略呈橢圓形。食道前半部爲發達之筋肉狀。中部食道球以下之食道漸次擴張而與胃 (Intestine) 相連，惟兩者之界限不明而難以劃分。神經環 (Nerve ring) 居中部食道球之稍後方。排泄孔 (Excretory pore) 不明顯。尾 (Tail) 呈圓錐狀，尾端狹小。其末端有三分枝狀突起，稱尾端小突起 (Mucro) 。肛門 (Anus) 居於體之末端附近，其角皮稍突出外方，形成一圓唇。

雌虫：　體長爲 722–855 μ (平均 777.4 μ)，體寬 11–16 μ (平均 14.7 μ) ，較雄虫細長。其陰門以下之部份漸次變狹。 陰門 (Vulva) 居於虫體中央稍後方，其長度約爲虫體總長之 70% 左右。陰門部之角皮並不突出。卵巢 (Ovary) 單一。其居於陰門後方者已退化，而僅形成一子宮囊 ( Uterine sac ) ，長度約爲陰門至尾端之 1/4。陰門前方之卵巢，向前伸長至食道腺末端附近，卵巢末端不反轉 (第二圖版, C, D) 。

雄虫：　體長爲 474–660 μ (平均 559.8 μ) ，體寬 9–14.5 μ (平均 11.9 μ) ，較雌虫短，體尾呈鐮刀狀彎曲，而與腹側略成直角。無交接囊 (Bursa) 。惟具有三對交接用尾部乳嘴 (Copulatory papillae)，居於尾之中央部稍後方，肛門正下方及尾末端附近各一對。前者略位於腹正中線上，於顯微鏡下易於識別。後兩者則較難於識別。交接刺 (Spicule) 爲略呈彎曲之半圓形刺。外側片 (Dorsal piece) 平均長約 15.23 μ。缺副刺 (Gubernaculum)。 (第二圖版，E, F) 。

Ⅱ. 體 形 測 定

線虫之分類，除上述虫體各形態可作爲根據外，尙常並依 Cobb 及 DeMan 兩氏之體寸法（Dimensions）以比較之。玆按兩氏之測定法比較著者與橫尾氏（19）之病原線虫如下（筆者之測定值係爲雌雄虫各 60 隻之平均）：

a.　Cobb's　Formula:—

| | | 口針 | 中部食道球 | 神經環 | 陰門或體中央 | 肛門 | 體長 |
|---|---|---|---|---|---|---|---|
| 雌 | 著者 | $\frac{1.49}{0.96}$ | $\frac{9.04}{1.64}$ | $\frac{12.20}{1.75}$ | $\frac{70.23}{1.88}$ | $\frac{95.02}{1.09}$ | 777.4 μ |
| | 橫尾氏 | $\frac{1.8}{1.2}$ | $\frac{9.4}{1.8}$ | $\frac{12.5}{1.9}$ | $\frac{71.6}{2.1}$ | $\frac{93.9}{1.3}$ | 650 μ |
| 雄 | 著者 | $\frac{2.05}{1.32}$ | $\frac{12.02}{2.04}$ | $\frac{15.23}{2.24}$ | $\frac{M}{2.11}$ | $\frac{94.75}{1.70}$ | 559.8 μ |
| | 橫尾氏 | $\frac{2.3}{1.6}$ | $\frac{11.3}{2.2}$ | $\frac{14.6}{2.4}$ | $\frac{M}{2.6}$ | $\frac{94.2}{2.1}$ | 520 μ |

b.　DeMan's Formula:—

| | | | |
|---|---|---|---|
| 雌 | 體　長 | 777.4 μ (722–850) | 650 μ (508–732) |
| | 體　寬 | 14.7 μ (11–16) | 15 μ (13–18) |
| | a $\left(\frac{體長}{體寬}\right)$ | 52.9 | 43.5 |
| | b' $\left(\frac{體長}{食道長}\right)$ | 12.9 | 10.6 |
| | c $\left(\frac{體長}{尾長}\right)$ | 20.0 | 16.9 |
| 雄 | 體　長 | 559.8 μ (474–660) | 520 μ (458–600) |
| | 體　寬 | 11.9 μ (9–14.5) | 14 μ (12–16) |
| | a | 47.24 | 38.0 |
| | b' | 10.08 | 8.9 |
| | c | 19.01 | 18.0 |

由上表觀之　著者之線虫較橫尾氏測定者稍爲細長，但於分類上之各主要點，各器官之百分比，雄虫尾部之彎曲度及尾端突起之三分枝等，均互相一致，應認爲與 Aphelenchoides besseyi 同種。

Ⅲ. 生　　　態

a.　生活史：一角田氏（14）記載所謂「黑粄病」之病原線虫生活史，謂其仔虫及成虫於稻穀內以假死狀態越年，俟播種並獲得水溫後漸次起眠活動，隨種子之發芽生育而沿葉鞘之內側葉脉間上昇，或於發芽當初逸出於地中而後侵入於其他幼小寄主。吉井氏（21）則謂：稻線虫心枯病之病原線虫越年於被害種子中，而於秧田期除侵犯幼稻外，尙能侵入於附近之健全苗漸次達到苗莖生長點後，由外部加害幼芽，至花穗生長期而侵入穎之內部。

上述角田，吉井兩氏所記載之生活史極爲類似。

b.　寄生部位：一角田氏謂：就生長至 4-5 寸之苗所調查之結果，可於第一，第二葉鞘及心

葉等最柔軟並養分豐富之部位檢出幼虫及卵，又每可被害種子之穎之內面或種皮之組織表面發現病原線虫。吉井氏則以石蠟切片鏡檢幼穗形成期之幼穗部及葉鞘之結果謂，病原線虫常發現於幼穗外域之毛茸間及花穎表面，而侵入於花穎內部者，亦實數不少。有時可於此等部位發現多數幼虫及卵。但此等線虫均存在於組織外，而無侵入於葯，花絲，子房及其他組織內者。

由上述兩氏之記載，一致認爲病原線虫爲外寄生 (Ectoparasitic)，而不侵入於組織內。

## 六、病原線虫之生理性質

### I. 培養試驗

Christie 及 Arndt 兩氏 (1936) (2) 首先報告，以生長有 Neurospora sitophila 之玉米培養基 (Corn-meal nutrient agar)，培養 Aphelenchoides parietinum 及 Aphelenchoides avenae 獲得良好結果，並謂此等線虫，僅能繁殖於雜有眞菌 (Fungus) 之培養基上。Todd 及 Athins 兩氏 (1958) (9) 乃將染有線虫心枯病之稻穀接種於蒸煮稻穀培養基上以培養本病病原線虫 Aphelenchoides besseyi，而由部份消毒之病穀子表面或內部生長蔓延之眞菌類，如 Alternaria, Curvularia, Helminthosporium 或 Fusarium 等乃成爲線虫生長繁殖所需之食料。彌富，西澤及古山氏 (1959) (10) 亦報告以 Alternaria citri, A. kikuchiana 或 A. brassicicola 與本病原線虫行混合培養而獲得成功。

本試驗係參考 Todd 及 Atkins 之方法進行之。將未去皮之稻穀倒入於 125 cc 容量之三角瓶內，厚約 5-6mm，加入適量之水後，於高壓殺菌器 (Autoclave) 中，以常法消毒之。另將染有線虫病之稻穀，以 0.1% 之昇汞水行表面消毒 3-5 分鐘後，再以無菌水充分洗滌，並將其移入於上述已消毒之稻穀培養基內，每瓶十粒，而後置於 25°C 恒溫箱內培養之。病種子雖經昇汞水消毒，但不致棲息於稻穀內壁之線虫死滅。同時，附着於稻穀內外之眞菌類亦不至完全死亡。因之，此等眞菌類於培養基內發育繁殖後則成爲線虫之食料。如此經一週後，培養基上已佈滿眞菌，病種子亦開始發芽，惟幼苗生長至某程度後則逐漸死滅。經二週後，可見少數線虫附着於瓶壁上，以後逐日增加線虫數目。至四週後，已有成千之線虫沿着瓶壁形成網狀或樹枝狀之線虫"虫落"，一般稱之爲 Lace-like appearance (第一圖版，A)。於顯微鏡下檢查之，可見多數線虫蠕動於瓶壁外，尙有線虫所蛻之皮及糊狀排泄物。

培養線虫時，培養基中之濕度能顯著影響線虫之生長繁殖。經多種比例試驗之結果，得知每 1gr 乾燥稻穀加水 2cc 之程度時，最適於線虫之繁殖。於此狀態下，培養瓶之內壁乃佈滿微細水滴。如瓶壁上凝集大型水滴 (過濕)，或全無水滴 (過乾) 時，均不適於線虫之生長。

培養基如放置過久，則水份漸次蒸散，影響線虫之繁殖。爲避免濕度減低計，筆者則以塑膠布包被瓶口，以控制適宜之濕度。

本試驗除以上述方法培養線虫外，尙用 Christie 及 Arndt 兩氏之方法，以馬鈴薯瓊脂培養基 (Potato nutrient agar) 培養眞菌 (如 Helminthosporium spp., Botrytis sp 等) 後，再移植線虫觀察之。惟本法對於線虫之繁殖效果不佳，而稻苗之生長反極良好，尤其以根部之發育爲甚。

### II. 各種菌類對病原線虫繁殖之影響

Todd 及 Atkins 兩氏 (1958) (6) 報告，線虫如與 Alternaria, Curvularia, Helminthosporium 或 Fnsarium 等菌類培養於蒸煮稻穀培養基時，其繁殖極優良，但如與 Penicillium 及 Aspergillus 混合培養時，則線虫繁殖甚少。著者於上述培養試驗中，亦發現類似 Todd 等氏之現象。茲爲明瞭菌類對本病原線虫繁殖之影響，乃選用 15 種眞菌，每種菌類預先接種於蒸煮稻穀培養基上，俟其生長旺盛後，再移植線虫於其上，而後置於 25°C 恒溫箱內。其培養四十日後

之繁殖情形如下表 (表中數字爲 125 cc 之三角瓶三瓶中之線虫平均數):

表三: 各種菌類對病原線虫繁殖之影響

Table III. Effect of various fungi to the multiplication of white tip nematodes.

| 菌 類 | 線 虫 數 | 稻苗之生長 |
|---|---|---|
| Helminthosporium oryzae | 16,209 | ++ |
| Helminthosporium sativum | 15,606 | +++ |
| Pestalotia sp. | 13,253 | +++ |
| Botrytis sp. | 12,441 | +++ |
| Fusarium sp. | 5,314 | +++ |
| Diplodia gossypina | 3,476 | +++ |
| Glomerella glycins | 2,810 | +++ |
| Pythium deBaryanum | 299 | ++ |
| Cercospora coffeiana | 194 | +++ |
| Lophodermium chaemacyparis | 52 | ++ |
| Calonectria sp. | 26 | +++ |
| Rhizopus nigricans | 22 | ++ |
| Penicillium sp. | 0 | +++ |
| Aspergillus sp. | 0 | ++ |
| Corticium sp. | 0 | — |

由上表可知, Helminthosporium oryzae 及 H. satvum 對本線虫之繁殖效果最佳,每瓶平均線虫數達 15,000 隻以上;其次爲 Pestalotia sp. 及 Botrytis sp.,其效果亦佳 (12,000 隻以上);再次爲 Fusarium sp., Diplodia gossypina 及 Glomerella glycins 等,其線虫之繁殖稍差;Pythium deBaranum, Cercospora coffeiana, Lophodermium chaemscyparis, Calonectria sp. 及 Rhizopus nigricans 等者較劣;而於 Penicillium sp, Aspergillus sp. 及 Corticium sp. 上則無線虫發育。

上表中,Penicillium 似能顯著抑制線虫之生長繁殖,而對稻苗本身之發育則無影響 (Corticium 則不然,對稻苗及線虫之生育均有阻碍),是否與 Penicillium 菌所分泌之抗生物質有關,則尙待今後之研究。

### III. 各種溫度對本病原線虫繁殖之影響

爲明瞭本病原線虫在不同溫度下之生長繁殖情形,乃按上法預先培養 Helminthosporium oryzae 於蒸煮稻穀培養基上,而後移植病原線虫,並置於 15°C, 20°C, 25°C, 30°C, 35°C 及 40°C 等 6 級不同溫度之恒溫箱中培養之。經五週後,觀察其繁殖情形,結果如下表:

表四：　各種溫度對病原線虫繁殖之影響

Table IV. Effect of various temperatures on the multiplication of white tip nematodes

| 溫　度 | 15°C | 20°C | 25°C | 30°C | 35°C | 40°C |
|---|---|---|---|---|---|---|
| 線　虫　數 | 0 | 17,582 | 9,155 | 755 | 67 | 0 |

由上表觀之，本線虫之繁殖適溫應在 20°C—25°C 之間，而以 20°C 爲其最適溫度。溫度如低至 15°C 以下或昇高達 40°C 以上時則不能繁殖。

## 七、種子處理試驗

橫尾氏 (1948) (19) 及 Cralley 氏 (1949) (3) 等先後報告本病係由種子傳染性線虫所引起。Todd 及 Atkins 兩氏 (1958) (6) 亦報告本病之被害種子爲唯一之傳播源。因此，以種子處理法減少本病之傳播源，實爲一防治上之良策。

Cralley 氏 (1949) (3) 首先報告，以 52-53°C 之溫湯浸種 15 分鐘獲得良好之防治效果。吉井氏 (1951) (22) 報告，冷水溫湯浸種法 (於 20°C 以下之冷水預浸 16-20 小時後移至 50-52°C 溫湯中浸漬 5-10 分鐘) 及溫湯浸種法 (直接將乾種子浸漬於 56-57°C 溫湯中 10-15 分鐘) 均有治病之效。Todd 及 Atkins 兩氏 (1959) (7) 報告種子先經過 24 小時之冷水預浸後，移至 51-53°C 之溫湯中浸漬 15 分鐘；或將病種子不經過預浸而直接浸漬於 55-61°C 溫湯中 10-15 分鐘均可殺死病原線虫，而對種子之發芽毫無影響。

冷水溫湯浸種及溫湯浸種處理，對於本病之防治效果，已見諸於吉井氏及 Todd 等氏之報告，惟其各所得之結果乃因人及隨地而稍有出入。玆爲究明本省最適宜之處理方法，乃分以下二項試驗之。

**I. 冷水溫湯浸種試驗**

將被害種子於 20°C 冷水中預浸 12 小時後，再分別浸漬於 48-55°C 之各級溫湯中，各浸漬 2，5 及 10 分鐘，而後移入預先培養有 Helminthosporium oryzae 之蒸煮稻穀培養基內培養之。經 4 週後，觀察線虫之繁殖情形如下表：

表五：　冷水溫湯浸種處理對本病之防治效果

Table V. Effects of cold-hot water treatment for control of white tip disease of rice

| 溫度 / 時間 | 48°C | 49°C | 50°C | 51°C | 52°C | 53°C | 54°C | 55°C |
|---|---|---|---|---|---|---|---|---|
| 2 min. | + | + | + | + | + | + | − | − |
| 5 min. | + | + | + | + | − | − | − | − |
| 10min. | + | + | + | + | − | − | − | − |

由上表之結果觀之，種子經預浸後，於 52～53°C 之溫湯中處理 5～10 分鐘，或於 54°C 溫湯中處理 2 分鐘均可使病原線虫死滅。本試驗結果，較之吉井等氏所得之結果，其致死溫度範圍稍高，即於 50～51°C 之範圍內尙無防治效果。如與 Todd 等氏之試驗結果相較，於同溫度下，本試驗結果不需 15 分鐘之浸漬時間，而可縮短至 5～10 分鐘即可收防治之效。

II. 溫湯浸種試驗

本試驗則不經過預浸處理，而直接將種子浸漬於 55～60°C 之各級溫湯中，各浸漬 2、5，10 及 15 分鐘，並立即以冷水冷却後移入上述培養基中培養之。其四週後之線虫繁殖情形如下表：

表六：溫湯浸種法對本病之防治效果

Tade VI. Effect of hot water treatment for control of white tip disease of rice

| 時間 \ 溫度 | 55°C | 56°C | 57°C | 58°C | 59°C | 60°C |
|---|---|---|---|---|---|---|
| 2 min. | + | + | + | + | + | + |
| 5 min. | + | + | + | + | − | − |
| 10min. | + | + | + | − | − | − |
| 15min. | + | + | − | − | − | − |

由上表之結果觀之，將病種子直接置入 58-60°C 之溫湯中，浸漬 10～15 分鐘，可使病原線虫死滅而毫不影響種子之發芽，且稻苗之生長較冷水溫湯浸種處理爲旺盛。本試驗結果，與吉井氏所得之結果相較，則較後者之有效溫度約高 2-3°C。此或因試驗方法之不同而發生差異。

## 八、討論及結論

寄生於水稻之線虫已見報告者共計 12 種 (20)，即：

1. Ditylenchs angusta (Butler) Filipjev
2. Tylenchorhynchus martini Fielding
3. Criconemoides komabaensis (Imamura) Taylor
4. Meloidogyne incongita var. acrita Chitwood
5. Pratylenchus pratensis (de Man) Filipjev
6. Radopholus oryzae (Von Breda de Haan) Thorne
7. Radopholus lavabri Luc
8. Radopholus gracilis (de Man) Hirschmann
9. Hoplolaimus tylenchiformis Von Daday
10. Aphelenchoides besseyi Christie
11. Xiphinema parasetaria Luc
12. Xiphinena campinense Lordello

其中除 Ditylenchus angusta 及 Aphelenchoides besseyi 2 種能於水稻地上部作外部寄生 (Ectoparasitic) 外，其餘 10 種線虫均惟能寄生於根部。

Ditylenchus angusta (Syn. Anguillulina angusta (Butler) Goodey; Tylenchus angusta Butler) (3) (17) (20) 於印度之 Lower Bengal 地區引起水稻之 Ufra disease。其病徵，據田中，內田兩氏(17)之報告雖類似本病，然依 Butler，Goodey 等氏 (19) 對 Ufra disease 之記載則謂：1) 葉鞘中央部份初爲綠色，但不久後則轉變爲褐色，2) 分蘖數不增加，3) 穀粒不變黑色，4) 不以種子傳染，5) 病原線虫較大。上述諸點均顯與水稻線虫心枯病 Aphelenchoides besseyi 不同。

根據筆者所觀察之病徵，與瀧元 (15)，橫尾 (19)，吉井 (21) 及 Todd and Atkins (6) 諸氏記載者相符合，再以病原線虫之形態及體形之測定值，復與橫尾氏 (19) 相近，因此筆者認爲發生於臺灣之水稻線虫病，乃爲 Aphelenchoides besseyi 所引起之線虫心枯病。

據橫尾氏(19)及 Cralley 氏 (3) 之研究，水稻線虫心枯病，以種子傳染，再據 Todd 及 Atkins 兩氏 (1959) (7) 之報告，本病之被害種子爲惟一之傳播來源，並謂病原線虫， 在乾種子內能維持其生活力達 23 個月，故種子處理爲防治本病最重要之對策。

本病之藥劑防治試驗已散見於各文献中，諸如 Tullis (1951) (8) 以 Methyl bromide 燻蒸種子，每 1000 立方呎空間用 1.25 磅，燻蒸 12 小時或用 1 磅藥劑燻蒸 15 小時後風乾數日，再以 0.5 磅燻蒸 15 小時。 Cralley 及 French 兩氏 (1952) (4) 報告：(1) 每 bushel 種子用 2 oz 之 Parathion dust (25%) 或 Systox on Carbon dust (50%)，(2) 以 1,000 倍 Mercury bichloride 水溶液浸種 12 小時，(3) Methyl bromide 燻蒸，每 1000 立方呎空間用 1.5 磅，及 (4) 每 bushel 種子用 2 oz 之 Aagrano dust (3-ethoxypropyl mercury bromide 3.5%) 等種子處理均可顯著減少本病之發生。日本群馬農試 (1953) (23) 以 Folidol 之 2,000 倍液浸種 12 小時；或移植前浸苗 24 小時。後藤及深津兩氏 (1953) (11) 以 Folidol 1,000～2,000 倍液撒佈於開花後。Todd 及 Atkins 兩氏 (1959) (7) 則以 N-244 (10% 3-p-chlorophenyl-5-methyl rhodaninei；試驗用藥劑) 處理種子獲得優良效果。惟上述各種藥劑用後，或發生藥害，或影響種子之發芽，或藥價昂貴而不適於實際應用，亦或因所供試之藥劑尙在試驗階段而未正式出廠等，故筆者認爲目前仍以溫湯浸種法或冷水溫湯浸種法最爲簡便， 且效果確實 。 按筆者之試驗結果則將種子於 20°C 冷水中浸漬 12 小時，後再浸漬於 52～53°C6 溫湯中 5～10 分鐘；或將種子直接浸漬於 58～0°C 溫湯中 10～15 分鐘者效果最佳。

本病主於秧田期傳染，故雖大部份使用健全種子，或消毒種子，但如於同一苗床內混有少數病種子時則有發病之慮，又因病原線虫附着於稻穀內越棲息，故應注意避免被害稻穀或混有病稻穀之堆肥使用於秧田。

## 九、摘　　要

就發生於本省水稻葉片及穗部之線虫病之病徵及病原線虫加以鑑定結果，知其爲 Aphelenchoides desseyi Chsistie 所引起之線虫心枯病，本病之典型病徵出現於穗孕期，被害葉片之尖端變呈白色透明狀或油浸狀黃白色。至後期，被害部漸次乾枯扭轉而呈紙捻狀。穗部被害時則變爲小穗，且多含不稔粒，呈黑褐色。其減收率達 50～60% 以上。

病原線虫：雌虫長度爲 722-850$\mu$ (平均 777.4$\mu$) ，寬度爲 11～16$\mu$ (平均 14.7) ，a＝52.9，b'＝12.9，c＝20.0。雄虫長度爲 447—666$\mu$ (平均 559.8$\mu$)，寬度爲 9—14.5$\mu$ (平均 11.9$\mu$)，a＝47.24，b'＝10.08，c＝19.0。

將經過表面消毒之病種子與各種菌類混合培養於三角瓶內之蒸煮稻穀培養基內觀察線虫繁殖情形之結果，與 Helminthosporium oryzae 及 H. sativum 混合培養時效果最佳。其次爲 Pestalotia 及 Botrytis，而如與 Penicillium, Aspergillus 及 Corticium 混合培養時則未見線虫生長。

培養線虫時，其培養基內之濕度，以每 1gr 乾種子加水 2cc 時最適於線虫之繁殖。於此情形下培養瓶之內壁可佈滿微細之水滴，如瓶壁凝集大形水滴或全無水滴時，均不適於線虫之生長。

將病原線虫與 Helminthosporium oryzae 混合培養於各種溫度之結果，知其繁殖適溫爲 20～25°C，15°C 以下或 40°C 以上則不能繁殖。

冷水溫湯浸種及溫湯種浸處理對本病有優良之防除效果，則將種子於 20°C 冷水中浸漬 12 小時後，再浸漬於 52～53°C 溫湯中 5～10 分鐘；或直接將種子浸漬於 58～60°C 溫湯中 10～15

分鐘可完全防治本病。

附註：本研究進行中承恩師羅清澤教授之懇切鼓勵與指導，又部份試驗得陳正德同學之幫助，併此謹致謝忱。

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## 十一、圖 版 說 明

**第 一 圖 版：**

圖A. 水稻線虫心枯病葉部病徵。

圖B. 病株之異常抽穗。

圖C. 健全稻穀（右）及被害稻穀（左）。

Plate Ⅰ :

Fig. A. Typical symptoms of white tip on leaves.

Fig. B. Abnormal heading of rice plant caused by white tip.

Fig. C. Effect of white tip on seeed ; left: normal seed, right: diseased seed.

**第 二 圖 版：**

圖A. 人工培養基上之網紋狀線虫 "虫落"。

圖B. 人工培養之水稻線虫心枯病病原線虫。

圖C. 病原線虫之雌虫。

圖D. 雌虫陰門部之放大圖。

圖E. 病原線虫之雄虫。

圖F. 雄虫尾部交接刺大圖。

Plaec Ⅱ :

Fig. A. Lace-like appearance of white tip nematodes on laboratory cultures.

Fig. B. Laboratory culture of Aphelenchoides besseyi.

Fig. C. Female of A. bessyi.

Fig. D. Showing vulva.

Fig. E. Male of A. besseyi.

Fig. F. Showing spicule.

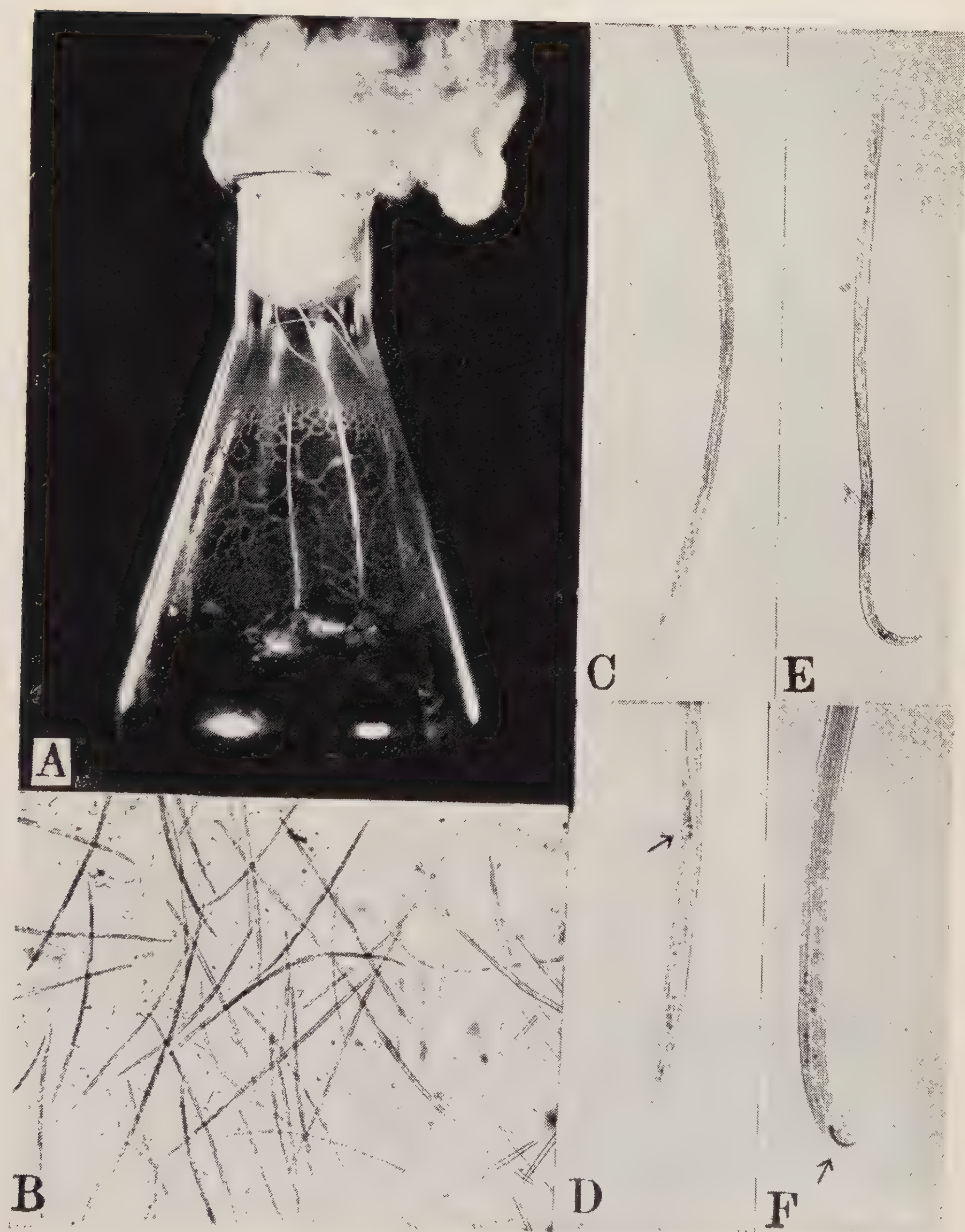
## 第 一 圖 版

## Plate I



第　二　圖　版

Plate Ⅱ



# STUDIES ON WHITE TIP DISEASE OF RICE

by

Moh-Jih Chen

## SUMMARY

White tip disease of rice is caused by an ectoparasitic seed-borne nematode, Aphelenchoides besseyi Christe. It resulted in yield reduction up to 50-60% in such susceptible rice varieties as Chia-nung 242 in the field. The tip or terminal portions of the diseased leaves become white or chlorotic for a distance about 3-6 cm, and these areas later are often dark or necrotic and frayed. Diseased plants are reduced in vigor and height, and produce small panicles. Affected panicles show excessive sterility, and the fertile florets at maturity have twisted or distorted glumes, and small, distorted kernels.

The causal organism: The worm-like female attains a size of 722 to 850 by 11 to 16$\mu$ (average 777.4 by 14.7$\mu$ ), a=52.9, b'=12.9, c=20.0. The male is also wormshaped, 474 to 666 by 9 to 14.5$\mu$ (average 559.8 by 11.9$\mu$), a=47.24, b'=10.08, c=19.0 with a spicule 15.23$\mu$.

To grow the nematodes in artificial culture, nematode-infested rice seed were introduced into tlasks containing a substance of steamed, unhulled rice, which had been inoculated previously with fungi. The fungi growing on the moist substrate within the flasks served as a source of food for growth and multiplication of the nematodes. Experimental results showed that the culture flasks would contain large numhers of nematodes when media were contaminated or inocnlated with those of fungi of Helminthosporium, Pestalotia or Botrytis. But flasks that overran by species of Penicillium, Aspergillus or Corticium contained no nematodes.

The most fevorable humidity of the substrate within the flasks for growth aud multiplicaton of the nematodes is to add two ml. of water into one gram of unhulled rice, so that thc inner wall of flasks is covered with numerous small drops of water at this rate.

The greatest growth and multiplication of the uematodes occurring at temperatures from 20°C to 25°C, and no growth was found lower than 15°C or up to 40°C.

Cold-hot water treatment was found to be effective to kill the nematodes without seriously reducing germinaton. The procedures are: seed were presoaked in cold water of 20°C for 12 hours, then immersed in hot water of 52～53°C for 5～10 minutes. In another study, a modified hot-water treatment was developed to omit the presoaking. Infested seeds were treated in hot water at 58～60°C for 10-15 minutes would kill all nematodes without any reduction in germination.

# 臺灣柑桔棉介殼虫生活史及防治法之研究

關　崇　智

# Studies on the Life History and Controlling Methods of Taiwan Cotton Scale Insect (Pulvinaria polygonata Cookerell) in Taiwan

by Chung-chih Kwan

## 一、前　　言

本省柑桔栽培事業，歷史極爲悠久，遠在十七世紀初葉，閩粵沿海居民大量徙居臺灣，並携有各種作物種子及苗木等，其中以柑桔苗木輸入爲最多，以供栽培用，故本省柑桔之栽培，殊爲普遍。在近幾年來柑桔園之開闢日益增加，除平地有大面積栽培外，現已擴及山邊坡地丘嶺廢墟以及其他荒蕪之地帶，甚至在本省北部海拔 1000 公尺以上之山地亦有栽培者。生長極爲良好，其生產量之提高殊爲驚人！故柑桔爲本省三大果王之一、乃爲爭取高額外滙之重要農產物，在對外貿易及農村經濟所佔地位極爲重要。本省氣候高溫多濕，最適各種害虫發生繁殖，如能對柑桔病虫害之防治工作力求徹底。以提高品質與產量，更能向國外大量推銷，爭取國際貿易市場，獲得巨額外滙，用以繁榮國家經濟，並早日完成三期經建計劃對復國建國之偉業貢献莫大。

柑桔類害虫殊多，據以往調查所知種類竟達100種以上，其中介売虫類佔有30餘種。惟對爲害柑桔介売虫類之研究常爲一般人所忽視，因該類害虫形體甚小，不易察見，但其危害情形都不遜於他種害虫，故爲柑桔重要害虫之一。今僅就臺灣棉介殼虫 Pulvinaria polygonata Cookerell 之生活史，習性及防治法等作進一步研究。筆者於民國四十八年春與同仁參觀員林柑桔園栽培情形時，見桔園內柑桔十有八九有介売虫類寄生其上，但一般危害情形不太嚴重，樹勢非常繁茂，其被害嚴重者，生長情形較正常樹株矮小，葉形細長變黃，開花雖多，但花梗瘦小，易於脫落，考其落花原因主爲介殼虫類寄生危害所致。有鑒及此。引起對臺灣棉介殼虫 Pulvinuria polygonata Cookerell 之研究動機，常藉假期或課餘之暇外出，本省北部各山地桔園作實際觀察，同時採集生活個體在室內飼育以觀察其生活習性及其爲害方法等。同時進行防治試驗，得能獲知撒佈藥劑之最適時期，藥劑種類以及藥劑配合量等，有所心得，爲文報導對防治柑桔棉介殼虫類之工作或者不無補益，因而以提高柑桔產量及品質，直接使桔農村經濟充裕，提高生活水準，間接促國家經濟建設提早完成，對反共復國大業有所貢献。

本文承蒙張教授書忱，吳先生蘭林及劉先生之中等熱心指導與不斷鼓勵，得能提早順利完成，特此深表謝意。

## 二、臺灣柑桔果樹介殼虫類之嚴重性

本省氣候温暖，雨水極爲調和，最適害虫發生及繁殖，故害虫種類之多非其他各省所可比擬。查柑桔果樹比較嬌嫩，最易受病虫害侵襲，爲害柑桔虫類甚多，分佈很廣，而其致害亦深。爲一般柑農所重視者首推斑星天牛 Anoplophora macularia (Thomson) 與潛葉蛾 Phyllocnistis citrella Stsinton 等。天牛爲害如嚴重時枝幹形成層四周皆被蛀食，雖多年結果之成樹亦難免於枯死。潛葉蛾則多蛀食新生嫩葉，如嚴重時，則全樹嫩葉殘枯萎謝，阻止生長，但此二種虫害顯

而易見，多數柑農尚能及時防治。依筆者目覩實情，在各地柑桔園中所遭受此類害虫之損害，尙不及介殼虫類之爲害嚴重。

爲害柑桔果樹之介殼虫類殊多，在本省約有30餘種，柑桔果樹不獨幹枝葉及果實受此類害虫之爲害，甚至尙有害及根部者。成樹受害輕者，枝葉萎黃，果少而劣，鮮味大減，降低經濟價值甚鉅，重者不但無果且漸漸乾枯。桔苗受害較輕者，枝葉枯黃，生長遲緩，重者則多數全株死亡。更有不少柑桔病害如煤黴病等，亦常藉此類害虫之排泄汁液以滋生，實爲柑桔果樹害虫中最嚴重者。惟因此類害虫體形微小，初生時肉眼不易察見，即至成長時若數目不多，一般柑農亦多忽視或誤認爲柑桔枝葉自生之瘡痂或斑點等，而不知其爲害虫，更不知其爲害情形嚴重可怕。迨至少數害虫逐漸孳生而滿佈全園各樹株釀成巨災時，亦多不知如何防治束手無策，任其自由猖獗爲害或有委諸於命運者對受害較輕之桔樹，任其自生自滅，受害重者，亦祇有斬伐充薪，常見各地柑桔園中，多年辛辛苦苦栽培之成樹，受此極小虫類之侵害，竟使全株桔樹趨於毀滅，損失之鉅，誠屬可惜。筆者去年在本省北部山地柑桔園觀察害虫發生情形，除天牛蛀食爲害外，其次介殼虫類最多，在每株桔樹上皆可找到介殼虫類寄生，其中尤以臺灣棉介殼虫 Pulvinaria polygonata Cookerell 最多，約達百分之二十左右，其危害情形在當時並未見有嚴重性，但對柑桔樹之生長頗有影響。至少對柑桔結果影響殊大，重者提早落果，無有收成或致收穫量減少，輕者柑桔果形瘦小，鮮味大減，影響柑農收入。至於新竹及臺北各地柑桔園中，介殼虫類亦皆遍發生，其受害情形，亦不次於山區桔園，由此觀之，介殼虫類誠爲柑桔樹之主要害虫，如不加以澈底防治，而任其自由蔓延爲害，將來本省桔園之發展將受莫大影響。特此爲文，提起一般人士注意，對介殼虫類危害柑桔之嚴重性，應及時謀法防治，尤其從事柑桔業者與研究昆虫學者以及有關政府人員，應急謀良法杜絕其爲害，以增加柑桔產量，提高品質，則對國家經濟建設及農村繁榮補益良深。

## 三、臺灣棉介殼虫 (Pulvinaria polygonata Cookerell) 之分類地位

隸屬同翅目 Order Homoptera Leach 1815

腹吻群 Tribe Sternorryncha Dumeril 1806

介殼虫總科 Superfamily Coccoidea Handlirsch 1903

硬介殼虫科 Family Coccidae Stephens 1829

## 四、分 佈 情 形

主要分佈於大陸沿海一帶，如廣東、福建及菲律賓、錫蘭、琉球、沖繩等地，在本省亦廣有分佈，如臺北、文山、羅東、臺中、員林、能高、花蓮等地，均有其踪跡。

## 五、食性及其寄主植物

爲寡食性 Oligophagous 種類，其主要寄主爲柑桔 Citrus 及月橘 Murraya 等，爲害其他植物，迄今尙未查見。在椪柑、桶柑及雪柑等栽培區域，或有月橘地方發生較多，在檸檬樹上繁殖者一般少見，最喜在生長良好之健全樹株上，生活在衰老之桔木或生長不良之樹株及苗木上者甚少。如將本種害虫卵粒接種於衰弱之桔樹上，雖能孵化爲若虫，但生活不久即行死亡，其若虫常寄生於嫩枝或葉之背面，若僅寄生於葉部時其成長期間延長，體形亦較小，形呈扁平，色澤較淡呈淡黃綠色，迨至成虫時其卵巢發良不完全，不能產卵。故於產卵前期其成虫常寄生於嫩枝上

，吸食枝部汁液，方能產卵，在此之際，其體背面稍行隆起，體色深濃，與在葉部寄生之個體相差極爲懸殊。至在柑桔果實幹部或根部等處則不能生活。在月橘及柑桔等寄主上，其卵粒孵化發育情形，及其個體之生活成長狀況，並無顯着差異。

## 六、為害方法及其為害狀況

以其刺吸式口器之喙部直接插入寄主組織中，吸食其中汁液以營生。凡經刺吸之部份，常現出淡色斑痕，影響其寄主之生長莫大。若虫常寄生在嫩枝或葉之背面，吸食其養汁，成長若虫或產卵前期成虫，均喜群居生活，一般多集聚在枝部吸收組織中汁液，致使寄主生長不良，樹勢減弱，過份嚴重時，可使全株枯死或局部枯萎。並能排洩大量排洩液緊附於葉面及枝部易於誘致煤病發生，影響寄主之光合作用。產卵前期成虫及成長若虫，常在枝部密集生活，虫體互相密接甚或部份互相重疊，此種情形，在柑柑園內最易察見。成虫於產卵時不食不活動，並停止排洩故此際對柑桔果樹爲害甚少。其成虫及老熟若虫在 3—4 月間出現最盛，其危害程度亦遠較其他季節嚴重。

其在本省分佈雖極廣泛，然全桔園普遍發生者很稀見，經往各地桔園觀察結果，多係局部樹株發生。終年發生或全桔園同時發生者計有圓介殼虫 Chrysomphalus aonidium Linne 及姬黑介売虫 Parlatoria zizyphi Lucas 但就其爲害程度而言仍以臺灣棉介売虫類 Pulvinaria polygonata Cookerell 最爲嚴重。寄生於柑桔類之介売虫類殊多，在同株樹上常發見有數種以上介殼虫類寄生爲害。臺灣棉介売虫與姬黑介売虫 Paralatoria zizyphi Lucas 及粉介売虫 Pseudococus spp. 等混合寄生爲害，最爲普遍。

## 七、產卵習性及發生代數之觀察

### 1. 一年中之代數

本種介売虫之飼育工作，自民國四十八年三月開始至民國四十九年六月止，共計十六閱月，獲知年生 3 代，在飼育期間從未見有雄虫出現，所有個體皆爲雌虫，推測其以孤雌生殖方法繁殖，當無疑異。在國外各書刊雜誌以及有關介売虫類研究論著等，均未見有詳細記載。以第 2 齡若虫開始準備越冬，一般在1～2月間生長最爲遲緩，越冬若虫期普通爲12～18日。越冬若虫在 3 月上旬化爲成虫。此等成虫在 4 月上中旬間開始產卵，卵期爲12～14日。其卵一般多在 4 月下旬至 5 月下旬間孵化率甚高，約達百分之九十以上。孵化若虫後約經40日後化爲成虫。在 6 月下旬至

表 1　臺灣棉介殼虫之若虫期調查表　(1959—1960)

| 世代數 | 時期 | 供試頭數 | 若虫期間(日) | | |
|---|---|---|---|---|---|
| | | | 最短 | 最長 | 平均 |
| 第 1 代 | 49年 4—5月 | 26 | 40 | 49 | 44.4 |
| 第 2 代 | 6—7月 | 36 | 43 | 65 | 48.2 |
| 第 3 代 | 9—10月 | 85 | 47 | 72 | 56.0 |

7 月初旬又行開始產卵，在 6～7 月間其孵期爲 9～10 日，其若虫期爲 40～50 日，在8月下旬

至9月上旬間成長爲成虫由此成虫，產卵所孵化之若虫開始越冬，在9～10月間卵期最長爲15日左右。

其若虫在發育成長期間，一般生長體形，寄生於葉部者遠較寄生於嫩枝者爲遲，因此在葉部寄生者，常多爬至枝部寄生，若虫期間，其個體常因生活環境不同而有顯着差異。在5月以後在柑桔園內可同時發見不同虫期之各種虫體，成虫之產卵期間及成虫出現季節均極不規則。

表 2　臺灣棉介殼虫之卵期調查表　(1959—1960)

| 世代別 | 時期 | 供試卵粒數 | 卵期間(日) | | |
|---|---|---|---|---|---|
| | | | 最短 | 最長 | 平均 |
| 第 1 代 | 48年 3—4月 | 1,388 | 10 | 18 | 12.3 |
| 第 2 代 | 6—7月 | 655 | 6 | 21 | 11.6 |
| 第 3 代 | 9—10月 | 2,807 | 8 | 17 | 10.9 |
| 第 1 代 | 49年 3—4月 | 923 | 14 | 29 | 15.6 |

其成虫若虫在自然環境中常遭各種天敵侵襲，此等天敵在4～10月間活動極爲活躍，因此而致死者甚夥，故在秋季所產卵粒過天敵活動盛期，得以生存越冬，以致翌年3～4月間盛行出現。

本種在臺灣1年發生3代，在日本有的種類 Pulvinaria spp. 一年發生 1～2 代，在印度有的種類 Pulvinaria maxima Green 一年發生 5～6 代 (Ramakrishna Ayyar 1925) 。

## 2. 產卵習性

成虫在產卵前期須生活在枝上，繼則體腹面緊粘於寄主植物表皮，其體背面質較堅便，色黑褐略帶灰色，有亮光，稍行隆起呈圓形，在中部多有不明顯之黑色縱帶1條，不分泌臘質物，體長約 4.7mm. 體寬約 2.7mm. 。卵巢成熟時體背面皮膚轉軟，體形轉爲扁平形，幅度增寬，腹面自周緣逐漸離開寄主植物表皮，背面尤其近周緣處顏色轉淡。體長約 5.0mm. 體寬約爲 3.5mm. 。

雌虫腹面周緣離開寄主植物表皮後，一般多向上方移動，或遷至葉背靜止，一時開始產卵。一般行動不活潑，其爬行距離爲 12～45mm. 多在白晝移動，自虫體轉軟形變扁平起至產卵開始止，經過期間約爲24小時。其一般所以向上方移動者，諒爲尋求新葉，亦有移向舊葉者，但爲數最少，至隨舊葉落地之雌虫或由卵囊孵化之若虫，其運動力均弱，大部分不能尋得寄主，或有寄主而無力爬行至寄主植物上而死亡。雌虫在葉裡多係分散靜止狀態，多數雌虫在同一葉內密集成群而生活者，亦屬常見。

雌虫開始產卵時，體背周圍蓋覆少量臘質物，周緣附有大量白色綿狀臘質物，近後方敍著長形成卵囊 Ovisac ，在產卵時稍帶暗綠色，約經4～5日間始可產畢，即產於卵囊內。虫體隨產卵數量而逐漸縮小，產卵完畢後，即行死亡，每一雌虫產卵粒數爲800～2400粒。平均爲 1400 粒左右，卵之長徑爲 0.22mm. 。

雌虫在產卵前期遷移之後，旣不取食亦不排洩，若將其置於其他植物上或器具上，亦可形成卵囊，其在產卵前期有遷移棲所習性，與其他近緣種類之產卵習性，廻然有異。

## 八、若虫孵化與齡期之檢索

本種若虫一般皆在早晨或夜間孵化，同卵囊中之卵約經4～9日孵化完畢，孵化後之空卵囊緊附於寄主植物上，很難剝離。初孵若虫具群居習性常在卵囊附近靜止，在午前8時以後開始活動，沿寄主植物體上下爬行，常選枝之凹陷處或葉之背面近葉脈處靜止，在葉表靜止者，極為少見。第一齡若虫移動距離約為 1 m，其移動時間約為數小時。一經固着於寄主植物後，則虫體漸轉為扁平，附着甚緊，很少有再行移動情事，除非寄主植物枯死。

第一齡若虫，體長約為 0.35mm初孵化時呈黃色體稍厚，肛裂 Anal cleft 很短，常開放，肛板 Anal Plate 殆達於腹部末端，迨附着於寄主植物後體形轉扁平，呈淡綠色稍帶白色，其肛裂關閉，其肛板稍行伸出於腹端，老熟若虫體長達0.7mm.以上。

若虫體色常隨生長脫皮而變暗，有時帶褐色，在背面中央生有1條黑褐色縱行條紋，體周生毛其數目隨生長而增加。觸角及脚亦隨脫皮而增大，惟其增加比率遠小體之增長。

若虫脫皮 3次，共計有四齡期變為成虫，其各齡期之形態主要區別如后：

1. 肛板 Anal plate 尖端各生長毛 (0.16mm.) 1 根，氣孔裂 Stigmatic cleft 不明顯，具氣孔刺 Stigmatic spines 3根，中間者最長，尖端呈圓形，體周之毛稍短。………第一齡若虫

肛板 Anal plates 尖端無毛，氣孔裂極明顯，氣孔刺較尖，……………………………………2.

2. 肛板 Anal plates 長約 0.055～0.059mm. 氣孔刺具有 3根者較多，體周之毛末端較粗無分枝，在體側前後氣孔裂間生毛 3根或 3根以上………………………………………………第二齡若虫

肛板長約 0.092mm. 氣孔刺有 3 根以上，體周所生之毛，很明顯，尖端粗而無分枝，在體側前後氣孔裂間所生之毛數約10根或10根以上…………………………………………………………3.

3. 氣孔刺在 4 根上下，氣孔裂間生毛數約10根第3齡若虫氣孔刺很多，極明顯，氣孔裂間所生之毛數在10根以上……………………………………………………………………………第四齡若虫

## 九、臺灣棉介殼虫與蟻之關係

其若虫及產卵前之雌虫，均能大量排洩液狀物，能以誘致蟻類來集。其主要有黑刺蟻 Polyrhachis dives Smith 及長脚黃蟻 Plagiapis longipes Jerden 等。其寄生於月橘者，則有舉尾蟻 Crematogaster spp. 與之共棲之。然經觀察結果，得悉此等蟻類既不能協助本虫阻止其天敵侵害，更不能助其遷移，僅能取食其所排洩之排洩物，其間並無密切之共生關係。

## 十、臺灣棉介殼虫防治方法之商榷

防治害虫方法殊多，除選擇優良苗木，改進栽培技術，利用人工捕殺，燈光誘殺以及食餌誘殺等外，則為藥劑防治與生物防治法二種。一般防治害虫所施用之藥劑概括為1.胃毒劑 Stomach Poison 2.接觸劑 Contact Poison 3.薰蒸劑 Fumigants 4.官能性殺虫劑 Systematic insecticide 等。此四類藥劑性質與功用各有不同，某種害虫應用某種藥劑防治，當視害虫之體軀構造為害情形，發生時期以及寄主生長概況而決定之。臺灣棉介殼虫體軀及生活習性等如上所述，口器為針狀之刺吸式口器，直接插入寄主植物之組織中，吸取養液，同時覆蠟質介殼或蠟粉覆蓋全身，以資保護，所以若施用胃毒劑則絕無效力，施用接觸劑則僅對無介殼或介殼較薄種類，或可收到防治效果，若藏身於堅硬介殼內之種類則殊難收效。防治臺灣棉介殼虫之為害，則首應觀察其生活習性，發生時期以決定施用藥劑種類，使用季節，如對症下藥，方可收效，否則任意施用藥劑，不僅無效易反發生嚴重不良影響。臺灣棉介殼虫越冬若虫在3～4月間，開始發育生長，群集柑桔

葉上為害，此季節為其為害柑桔最嚴重時期，故在此際施用藥劑防治最有效，普通噴佈夏油乳劑40倍液，在開花期內避免噴佈或噴佈松脂合劑18～20%防治之。其成虫老熟若虫以及卵囊等藥劑之抵抗力甚强，一般使用松脂合劑及其他油類乳劑等均無大效，故施用富粒多 Folidol E605 或馬拉松 Malathion 乳劑2000倍液及 P. M. 乳劑等 1800～2000 倍液可以奏效，其若虫在11月間為幼齡時期，對藥劑之抵抗力較弱 故乘此季節施用藥劑防治 則可防止在翌年春季發生蔓延危害，因而在11月間施用藥劑最為有效，可供經營柑桔業者參考。本省產介売虫類，依其習性可以概括為3型如下：

1. 一年發生1代，成虫出現常有一定時期，其第一齡幼虫出現時期亦有一定季節者，若虫往往在2月間發生最多，如瘤介売虫 Tachardina theae Green et Mann 為害茶樹及其他栽培樹木，施用藥劑防治本虫最適時期為1月初旬至2月中旬間收效最大。

2. 一年發生 2 代者 ，成虫在冬季產卵 ，其成虫及各齡若虫終年均可發現 ，如圓介売虫 Chrysomphalus aonidium L.

3. 一年發生2代以上者，此類介売虫在本省整年均能繁殖，成虫及各齡若虫在一年任何季節均可採得。如姬黑介売虫 Parlatoria zizyphi Lucas 綠介売虫 Coccus viridis Green 及粉介売虫 Pseudococcus filamentosus Ckll 等。成虫對藥劑之抵抗力較强，其他大部種類體被堅硬之介売或蠟質，覆蓋全身，用以保護，故施用藥劑防治此類成虫實難收效。惟其若虫對藥劑之毒殺抗力較弱，故前述1及2兩型若虫出現季節概有一定，故可規定施用藥劑時期，如能按時防治絕無發生可能。第3型其成虫終年均有出現，故撒佈藥劑時期無法確定，致使施用藥劑防治難能收效。

施用藥劑防治臺灣棉介売虫，固屬有效，若使用藥劑種類不適，施用技術不良，藥量濃度配合不恰，時期不宜，不特不能奏效，甚或得到不良後果，如害及果樹，殺滅天敵甚至傷人，結果得不償失。更有甲園施行防治，隣園則任意繁殖，則其收效亦必微乎其微。施用藥劑防治虫害在本省農村極普遍，近年來對於殺虫劑之毒理，及效力試驗，深具研究，防治害虫學術進展，已有一日千里之勢，政府農業機關與研究昆虫學者對於防治此類虫害，年來亦多力求藥劑以外之其他有效方法，如利用寄生蜂或其他自然天敵等之生物防治法 ，以圖彌補藥劑所不及者 。利用生物防治，尤其是利用寄生蜂如臺灣棉介売虫之有力天敵 ，有一種小蜂名為 Aneristus ceroplastae Howord 其寄生率頗高約達90%以上，尤其在桔葉裡面生活之虫體除第一齡若虫及成虫外，被寄生者最多，此蜂於一寄主體內完成其生活史，當羽化為成虫時，在寄主體背面中央或後方鑿成圓形小孔外出，再尋其他寄主產卵繁殖。又卵及若虫則有姬瓢虫 Scymnus spp. 及其他小形瓢虫類，捕食其卵塊及將產卵之成虫則有棲黃黑翅瓢虫 Cryptolaemusm montrouzicri Muls 專捕食之此等天敵對臺灣棉介虫之繁殖影響莫大。

利用天敵防治介売虫類，一方面可避免施用藥劑弊端，另一方並不受園疆之限制，如某種寄生蜂或天敵可以防治某種虫害，一經研究鑑定，施行人工保育，大量繁殖之後，施放於桔園內可抑制臺灣棉介売虫之繁獘與蔓延，甚至隣接桔園內之棉介売虫均可全部消滅，此法為防治本虫最優方法，並對其他介売虫類亦可收到若干抑制效果。

## 十一、結　　論

臺灣棉介売虫在本省平地各桔園均有發生，在北部山地桔園亦有發見，尤其北部柑桔園發生較為普遍。一年發生3代，其越冬若虫，在3～4月間開始發育生長，具群棲性，常集聚桔葉上，為害嚴重時，則可擴延於幼嫩枝部，在此季節為其發生猖獗時期，故此際施用藥劑防治較為有效。本虫在11月間若虫為幼齡期，對藥劑之抵抗力甚弱，應乘其未充分長成老熟時，施用藥劑防治

最爲有效。一般施用夏油乳劑40倍液或松脂合劑及其他乳油劑等，均獲顯著奇效，惟其若虫在老熟時，體壁堅厚，並有臘質棉狀物蓋覆，適應環境能力較强其對藥劑毒殺力之抗性增强，因而使用乳油劑則難收卓效。故須改用有機氯化烴殺虫劑或有機燐劑等有效。在北部山地桔園有噴佈馬拉松乳劑 Malathion Emulsion 1500～2000 倍液或用 P.M. 乳劑等，殊見功效。近年來本省農村施用藥劑防治桔園虫害，極爲普遍。一般柑農對藥劑施用技術日益改進，選擇藥劑種類亦極謹愼，兼有政府農業機關之督導與鼓勵，對防治此類害虫極力尋求有效防治法，當值今日核子時代農藥發明，日新月異，殺虫毒力之大，殊令人驚異！防治柑園棉介殼虫類之危害，如施用藥劑時期適宜，藥量配合恰當，當能全部消滅，惟用藥劑防治害虫有很多弊端，無可諱言，尋求生防治方法，利用寄生蜂類及瓢虫類以抑制其發生，澈底根絕乃爲上策。

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圖版說明

1. 產卵前期之雌虫及生長若虫之群居狀況。
2. 產卵前期之雌虫。
3. 生長在葉之雌虫體淡色扁平。
4. 在葉裏產卵之狀況。
5. 產卵前雌虫體呈扁平。
6. 雌虫業已形成卵囊。
7. 雌虫形成卵囊之期間。

# STUDIES ON THE LIFE HISTORY AND CONTROLLING METHOD OF TAIWAN COTTON SCALE INSECT (pulvinaria polygonata Cookerell.) IN TAIWAN

by

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## SUMMARY

The present paper is a report of observations on the Taiwan cotton scale insect (Pulvinaria polygonata Cookerell) couducted in Taichung, Taiwan, during 1959 to 1960.

So far as I know, there are many species or varieties of citrus cultivated in this island. According to the published reports, there are 30 species or more scale insects have been found to damage the citrus trees. These insects attack the leaves and branches of the citrus causes the serious pests during the growing period Date about the life history and method of effective control studied in the this island are very important to us. The results of observations on life-cycle and habits of this insect presented in this paper are base on the obseruationason studies of in door-feeding as well as depend upon the field observations.

This kind of scale insect is widely spread on the plain. Its eggs nymphes and adults can be successfully transfered from Murraya to citrus or vice versa; on the other hand, this insect may sometimes attacks the Murraya in the field and no physiological races are recognized in the species.

There are 3 or 4 generations annually, the adult females emerge in March and April, even sometimes in the middle of the June or to the late August with matured nymphal stage cross over the Winter. No male insect has been found. The body of the adult females are flattened and softed, this insect often migrating to the lower side of the leaves, settle themselves, without eating, and then begin to oviposit immediately. The adult do not oviposit if there is no branch to feed them. each egg mass is formed in 4 or 5 days, and contains about 1400 eggs on an average. They hatch in 9-12 days and the nymphal stage lasts 40-50 days in the spring and summer, but it takes 120 or more days during the winter season. The nymphes have 4 instars, and feed on the branches and on the leaves.

This species is severely attacked by some of the coccinillids and a very large proportion of nymphes in late stage were parasited by the natural enemy named Aneristus ceroplastae Howard in spring to the late summer.

The results on the study of chemical control, the auther wish to point out that Malathion 5E emulsion desolved in 2,000 times of water and the P. M. emulsion of 1500 to 2000 tims of water are the most effective materials for protection and control.

# 植物吸水特性之研究[1)]

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## 一 緒 言

植物消耗水分之狀況固因種類不同而異，即同一植物又因季節及一日間之氣候不同其消耗情形自亦不一；關於此項問題之研究，不但可以瞭解各種植物之吸水特性，且可供作各種植物合理用水之參考。筆者爲探討此項問題，曾引用恩師玉井虎太郎博士之平型自動灌水器 (6,7,8,9) 栽植甘蔗及玉蜀黍，並自行附加毛細管，以觀察水頭移動情形，藉以瞭解各種植物在一日間不同時刻之消耗情形。復應用此種方法測得日蝕時甘蔗及玉蜀黍吸水情形與平日不同之現象，而現示吸水作用與蒸發量及吸水作用與氣溫間之相關係數頗高。然利用此一方法同時進行數種植物對水分消耗情形之比較試驗頗爲不易。

氣溫之高低、測定場所之狀况及植物地上部之狀態對植物根吸水作用之影响如何，亦一重要問題。筆者乃於民國四十六年自行設計吸水電動記錄器，以觀察及測定不同植物，在不同場所於一日間對水分之消耗現象。

爲明瞭植物地上部之狀態對根部吸水作用之影响，曾將香蕉植株(1)撕破葉片、(2)折彎葉柄、(3)刈除葉面及(4)刈除假莖等處理，綏將上述各種觀察及測定所得結果，整理成篇，以供參考，並祈不吝賜教。

本文蒙恩師玉井虎太郎博士及臺灣省立農學院植物學系系主任易希道教授鼓勵與指導，無限感激，又得王博仁君協助裝置電動記錄計，並此申謝。

## 二 研究方法及材料

爲使供試植物儘量接近田間之生長狀態，本試驗用如圖 1 之木箱，內置玉井氏之平型自動灌水用素燒(P)，其上盛滿土壤，然後將供試植物栽植於箱內，俟植物生長旺盛後始作吸水試驗。在此箱內，植物生長所需之水分完全由素燒部供給。即植物從土壤中吸收水分時，土壤即從素燒表面吸收等量之水分。因素燒以玻璃管與貯水槽 (R) 相連接，故素燒亦可由貯水槽吸收相等於被植物所吸收之水量。因此僅測定貯水槽內所減少之水量便可測知植物之吸水量。爲防止水分經木箱表面蒸發，箱面皆用塑膠布覆蓋。又避免水中產生綠藻阻害水分之流通，玻璃管及貯水槽均以內面黑色外面白色的紙遮蔽之。

植物吸水之際，若切斷素燒與貯水槽之連結，而與加設之毛細管(Cap)連結時，因此毛細管內之水頭移動的速度與吸水速度成比例，故觀測任何時間內之水頭移動速度，即可知該時間之吸水情形。要測定在某時間之吸水速度，首先將貯水槽 (R′) 內之水引進於毛細管內，而至管內之水由先端流出後切斷貯水槽 (R′) 與毛細管之連結，然後將素燒與貯水槽間之連結，藉中間三面活栓切換於毛細管，即可見到管內之水隨着植物之吸收而趨向植物方移動。此時除保持毛細

1) 本文大部分蒙國家長期發展科學委員會資助研究，特此謹誌申謝。

管爲水平狀外，並應保持毛細管與貯水槽 (R) 內之水面同等高度，以防水面高低不同而影响吸水速度。本文部分結果曾用此法測定。但因夜間實施較爲困難，故不易用此法作數種植物之比較觀察，故於數年前開始用電動記錄計作吸水變化之連續記錄。所採用之自動記錄計係將玉井氏之自記微流量計 (12.16.26) ，加以改良乃筆者以手工作成者。其構造及使用法叙述如下。

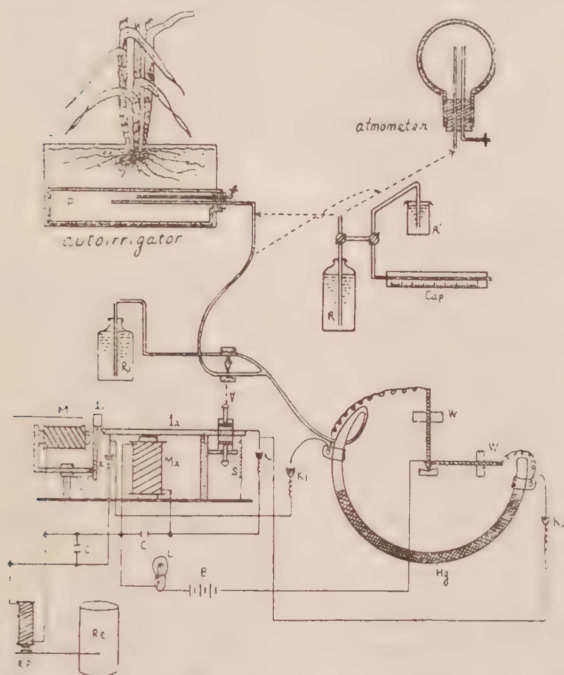



圖1. 自動灌水裝置 Atmometer 及電動吸水計之構造圖。

Figure 1. Diagram showing the construction of the apparatus used for estimating absorption and evaporation.

B…蓄電池 (Battery)
C…蓄電器 (Condenser)
K…接點 (Contact point)
R…貯水槽 (Water reservoir)
P…素燒槽 (Porous cup)
W…錘 (Balancing weight)
Hg…水銀 (Mercury)
V…電動瓣 (Electric valve)
Re…記錄用筒 (Recording drum)
Rp…記錄用電磁石(Electric magnet for recording pen)
$M_1$·$M_2$…電磁石 (Electric magnet)
1…槓杆 (Lever)
S…彈簧 (Spring)
Cap. 毛細管 (Capillary tube)

本裝置如圖 1，係由三個主要部分組成，(1)電動瓣，(2)環型玻璃管及(3)電動記錄部。電動瓣以兩個大小不同的電磁石($M_1$ 及 $M_2$)構成。爲增加牽引力，特將 $M_2$ 作成 U型。電動瓣右邊環型玻璃管，管徑有0.65cm，0.55cm，及0.4cm 三種，視植物之種類及大小而加以選擇使用，藉節省水銀用量並較爲方便。環型直徑約爲 12～14cm 。環型玻璃管之一端呈尖狀，由此引出小橡皮管，並經Y型小管再以兩條小橡皮管分別通過電動瓣上下兩側而連結於補水瓶 ($R_1$) 與自動灌水裝置之素燒部。如是環型玻璃管內之水將成爲植物之水源。當玻璃管內之水被吸收之際，因管內水銀的作用，此環型玻璃管之尖狀部次第趨向與鐘針相反方向旋轉，並至一定的高度時，附設於玻璃管上之金屬線即與接點 $K_1$ 內之水銀接觸，在此瞬間，蓄電池內之電流即經此而流入電磁石 $M_1$ 中，而賴 $M_1$ 的作用將縱槓杆($1_1$)向電磁石 $M_1$ 方向牽引，由彈簧的作用，横槓 ($1_2$) 向上方彈跳，並將Y型小管通至素燒部之小橡皮管壓塞。同時於相對位置， Y 型小玻璃管與補水瓶 ($R_1$) 間連接之小橡皮管即因横槓之彈跳而被開放。又因錘的作用，環型玻璃管巧恰朝向與上述相反方向旋轉，將補水瓶 ($R_1$) 內之水吸進玻璃管即完成補水作用。當由補水瓶內吸進一定量的水於玻璃管內時，另一個附設於玻璃管上之金屬線即與接點 $K_2$ 內之水銀接觸，電池內之電流仍於接觸的瞬間流進另一電磁石 $M_2$ 中，並發生曳引力而將 $1_2$ 向下方牽引。於是補水用小橡皮管再次被壓塞，而給水管即被打開，繼續供給水分。因補水作用在瞬間內完成，故對於植物之水分供給並未斷絕。每當消耗一定的水量時，即當金屬線與接點 $K_1$ 內之水銀接觸時，有一部分電流將流進於記錄用電磁石 Rp 中，結果在一定速度旋轉之圓筒上劃上一條縱線。在圓筒上記錄下來之縱線，因其密度與吸水速度成比例關係，故事後可用 micrometer 測定兩條線間

之距離即可知吸水之速度。又以容積法測定補水瓶內所減少之水量，再以該時間內之記錄線數除之，即可得每次消耗的水量。惟每次的消耗水量，可視實際需要加以調節，而此種調節乃將接點 $K_1$ 及 $K_2$ 之高度略加移動即可達成調節的目的。

供試材料爲甘蔗、玉蜀黍、香蕉、含羞草、仙人掌、虎耳草及落地生根等七種植物。均須待其生長旺盛後始行測定。

## 三 實驗結果

關於植物吸水作用在一日間之變化與外界因子之關係，筆者曾發表部分結果 (14.15.29.)。惟以往實驗缺少比較測定，致未能全部論及。茲將以往及最近所得之結果，共同介紹植物之吸水特性於下。

### （1）植物在晴天一日間吸水之變化與氣候因子

由於植物根之吸水作用受氣候變化之影响甚巨，故吸水在日中之變化極爲顯著。惟因植物種類不同，吸水作用對於氣候的變化，各示不同之反應。據筆者之觀察，上述七種供試材料中，甘蔗、玉蜀黍、香蕉及含羞草等植物之吸水作用，對日照、氣溫及蒸發量等之變化示正相關。但仙人掌、落地生根及虎耳草等植物適得其反。茲分述兩種不同反應之植物吸水情形於下：

一般對日照、氣溫及蒸發量成正關係的植物，其吸水受氣候變化之影响極顯著。因此在一日間，吸水之變化極顯著。在晴天一般植物之吸水量隨早晨日出而作急劇增加，最盛期通常在正午

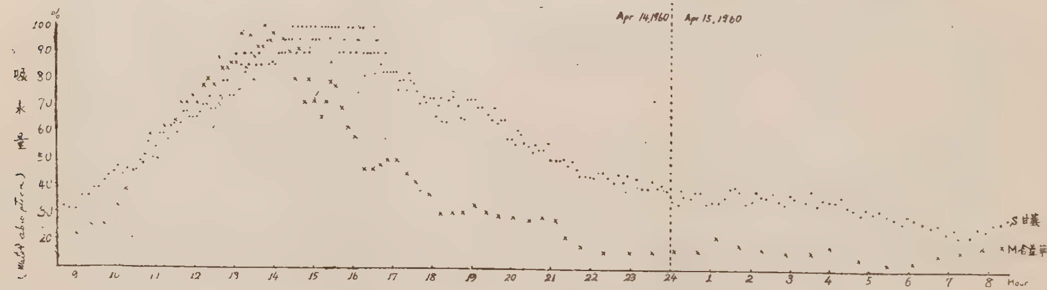



圖2. 甘蔗及含羞草之吸水作用在一日間之變化情形

Figure 2. Daily changes in water absorption by Sugar Cane and Mimosa pudica plants.

表1. 數種植物吸水之最高及最低時刻

Table I. Time of maximum and minimum water absorption of several plant species.

| 植物 Plant | 吸水最低時刻 Minimum water absorption (hour) | 吸水最高時刻 Maximum water absorption (hour) |
|---|---|---|
| 甘蔗 Sugar Cane | 7：10—7：20 | 14：10—15：30 |
| 香蕉 Banana | 8：00 | 13：48—15：30 |
| 含羞草 Mimosa Pudica | 5：20 | 13：40—13：49 |
| 仙人掌 Cactus | 13：00—15：00 | 19：10 |
| 落地生根 Bryophyllum | 13：38—14：15 | 16：30—17：00 |

後，此後復隨光度之減少而作急劇減少，但至黃昏後漸趨平隱（請參閱圖2,4,10），而以日出前吸水最少。然經分別觀察各種植物吸水之變化情形，可知香蕉、甘蔗及含羞草等植物，早晨開始增加吸水量的時間均各有異。如香蕉約於8時左右，但含羞草更早，約於5時左右，而甘蔗則居於兩者之間，約於7時左右。於日中，其吸水達到最盛期的時刻及範圍（期間）亦各有差異。香蕉保持吸水最盛期之時間最長，因此其曲線的頂端呈鈍頭狀。含羞草保持最盛期的時間較短，其曲線的頂端銳尖，甘蔗位於兩者之間（圖2及表1）。晝夜吸水量之差異亦因植物種類不同而異，可知有顯然區別的特性（圖2,4,10）。

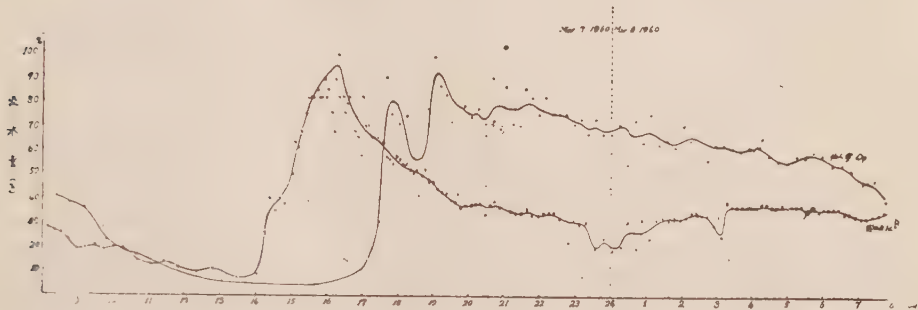


圖3.　仙人掌與落地生根之吸水作用在一日中之變化情形

Figure 3.　Daily changes in water absorption by Cactus (Op) and Bryophyllum (B) plants.

其次於同一時間測定的仙人掌及落地生根等植物之吸水量，於早晨，隨光度、氣溫及蒸發量之增加而反減少，並於日中，光度較强時即告停止。其吸水變化之曲線恰與上述甘蔗及香蕉相反。吸水最盛時間，仙人掌約於19時左右，而落地生根約於17時前。最低略與甘蔗、香蕉等之最高時刻符合。此兩種植物不僅其吸水最高時刻及開始吸水之時間廻異，且夜間之吸水情形亦各有差異（圖3）。由圖3可知落地生根之吸水於最盛期後減少之程度遠較仙人掌爲顯著，並至午夜有再增加的趨勢。此現象與至吸水最盛期後，以極緩慢的速度減少之仙人掌廻然有異。由以上可知各種植物之吸水在一日間之變化雖極類似，但具有顯然區別的特徵。

表2.　戶外香蕉與玻璃室內香蕉吸水之最高及最低時刻之比較

Table 2.　Time of maximum and minimum water absorption Banana grown insides of green house and on outdoors.

| | 吸水最低時刻 Minimum (hour) | 吸水最高時刻 Maximum (hour) |
|---|---|---|
| 香蕉 Banana (in open air) | 7 : 40 | 13 : 55——15 : 05 |
| 香蕉 Banana (in green house) | 8 : 15 | 13 : 56——15 : 37 |
| 蒸發量 Evaporation from atmometer (in green house) | 8 : 15 | 15 : 23 |

（2）香蕉在不同場所於一日中吸水情形之差異

上面係植物處在同一環境下測得的結果。筆者為明瞭吸水之一日內變化與測定場所的關係，曾將兩株香蕉分別置於玻璃室與室外，進行吸水之自動記錄，得如圖4及表2的結果。觀其結果，可知室外香蕉在晝間吸水之變化較玻璃室內香蕉顯著，且於早晨吸水開始增加的時間亦遠較玻璃室內香蕉為早。惟吸水呈現最高值之時刻略一致。又就晝夜間之變化情形而言，放置玻璃室內的香蕉，其吸水之最高與最低的差異較為顯著。在晝間，吸水至最盛期後之減少程度，戶外香蕉較為緩慢，且黃昏後之吸水量亦較室內香蕉為多。

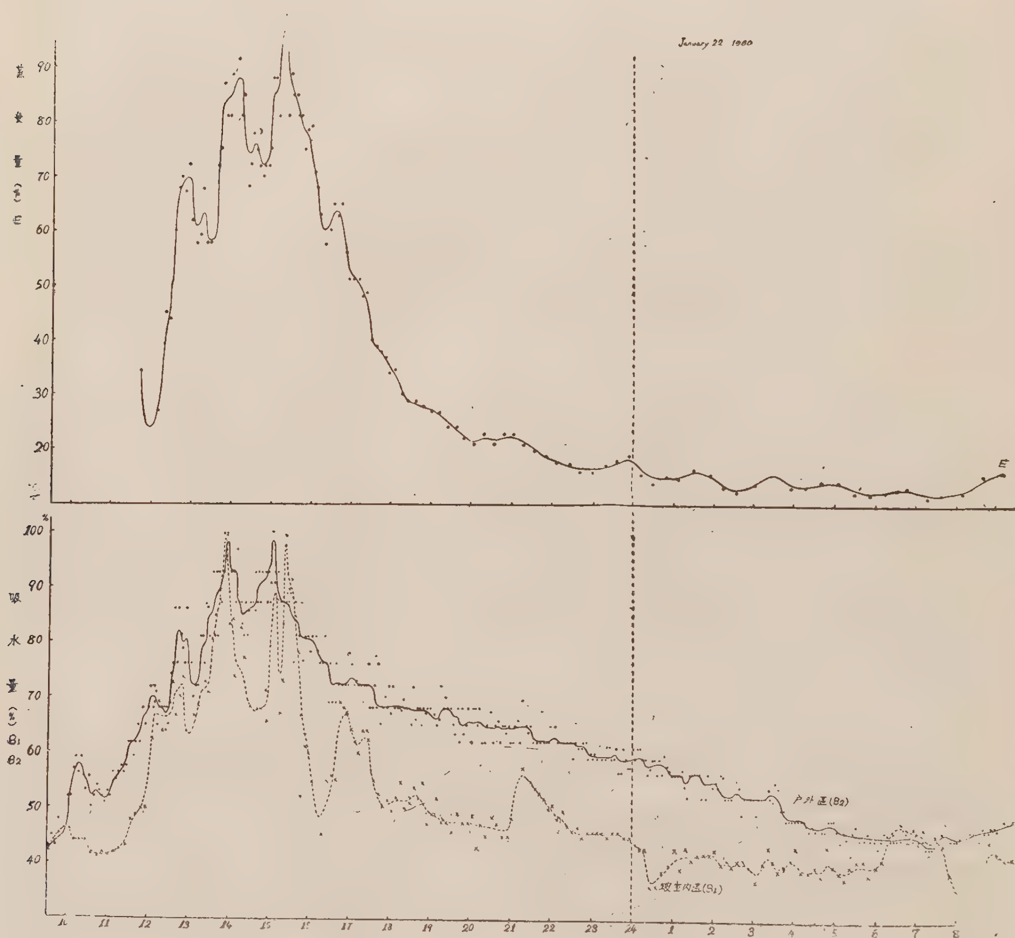



圖4.　室內香蕉與室外香蕉在一日間之吸水變化情形比較

Figure 4.　Comparison of daily changes of water absorption between Banana plants grown insides of green house ($B_1$) and on outdoors ($B_2$)
E………Evaporation from atmometer.
$B_1 \cdot B_2$………Water absorption in Banana plants.

### （3） 吸水量與天氣之關係

植物之吸水受大氣中氣候因子變化之影響極顯著，故每日之吸水量，由於當天氣候之不同而發生顯著之差異。玆將各種不同氣候情況下所測得數種植物之吸水量列示如表3。

表3. 天氣與一日間吸水量之變化

Table 3. The effect of weather upon the daily absorbing amount of water by Sugar Cane and Banana plants.

| 植物 Plant | 晴天 Fine | 陰天 Cloudy | 雨天 Rainy |
|---|---|---|---|
| 甘蔗 Sugar Cane (in green house) | 85 | 35 | 18 |
| 同上百分比 Relative value (%) | 100 | 41 | 21 |
| 香蕉 Banana (in green house) | 615 | 383 | 122 |
| 同上百分比 Relative value (%) | 100 | 62.2 | 18.2 |
| 香蕉 Banana (in open air) | 545 | 500 | 87 |
| 同上百分比 Relative value (%) | 100 | 91.7 | 15.9 |

由上表可知甘蔗與香蕉，在不同天氣情況下，其吸水之減少情形幾乎相同。但吸水量與天氣之關係視測定場所不同而有莫大差異。如於陰天，戶外香蕉與室內香蕉所顯示的反應迥然有別。即在陰天，室內香蕉之吸水量僅爲晴天之60%，但戶外香蕉佔90%。此種差異實值注意。

植物一日之吸水量，除受當日天氣陰晴的影響外，尙受當天氣溫高低之影響。在冷天，香蕉之吸水量僅爲暖天之45%（表4），而吸水在日中之變化亦不顯著（圖5）。由此可知吸水受低溫之影響極爲顯著。至於低溫對蒸散作用之影響；筆者利用重量法測得結果如表4。即低溫對蒸散作用之影響，較吸水作用所受之影響爲輕，此種現象值得注意。

表4. 香蕉一日之吸水量、蒸散量與氣溫

Table 4. Effect of the temperature upon the daily absorbing amount of water and transpiration by Banana plant (in green house.)

| 日期 (1) | 氣溫 (°c) (2) | 吸水量 (cc) (3) | 蒸散量 (gr) (4) | 蒸發量 (cc) (5) | 備註 (6) | 日期 (1) | 氣溫 (°c) (2) | 吸水量 (cc) (3) | 蒸散量 (gr) (4) | 蒸發量 (cc) (5) | 備註 (6) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec 21,1960 | 15-26 | 1010 (100%) | 1020 (100%) | 23.2 | Fine | Dec 30,1960 | 8-13 | 440 (44%) | 640 (63%) | 22.3 | Fine |
| Dec 22,1960 | 15-26.2 | 1070 (100%) | 1040 (100%) | 20.6 | Fine | Dec 31,1960 | 9-15 | 435 (41%) | 530 (50%) | 21.0 | Fine |
| Dec 23,1960 | 16-28 | 1060 (100%) | 1060 (100%) | 20.9 | Fine | Jan 31,1961 | 11-19 | 510 (48%) | 510 (48%) | 20.9 | Fine |
| 平均 Average | — | 1047 (100%) | 1040 (100%) | — | — | 平均 Average | — | 462 (44%) | 560 (54%) | — | — |

(1)………Date.　(2)………Air temperature　(3)………Absorption a day.
(4)………Transpiration a day.　(5)………Evaporation from atmometer.
(6)………Remarks.



圖5.　在低溫情形下香蕉吸水作用在一日中之變化情形

Figure 5.　Daily changes of water absorption of Banana at cold temperature.

在適當溫度情形下，香蕉在一日間之吸水量殆與蒸散量相等。但在低溫情形下，因吸水作用受低溫之影響較蒸散作用爲顯著，故將產生蒸散量與吸水量不均衡現象，並容易引起水分代謝之混亂現象，致使植物體發生缺水現象。

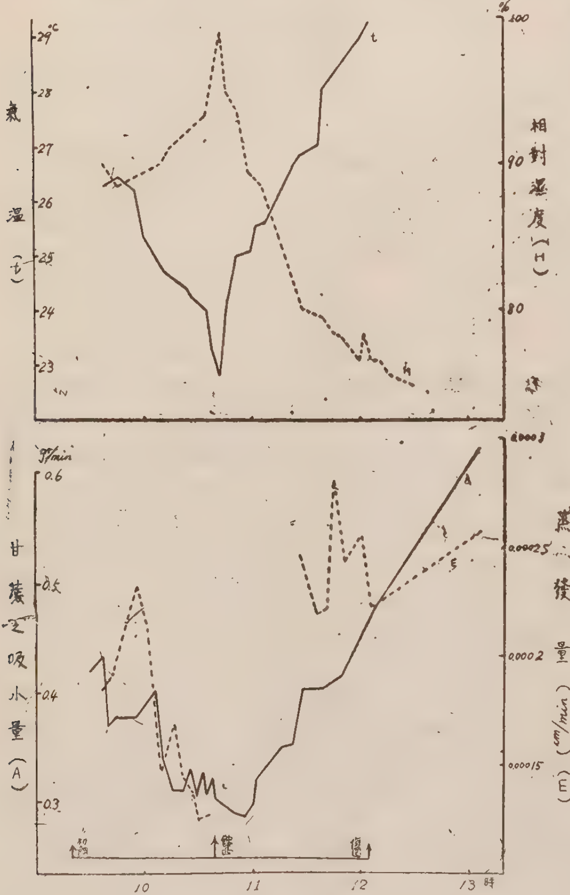


圖6.　1948年5月9日於臺中日蝕時甘蔗吸水量與外界因子之變化情形

Figure 6.　Graphs showing the changes of the absorption of water each hour in Sugar cane and its enviromental factors observed at Taichung during the course of the solar eclipse occurred on May 9, 1948.

t…Air temperature.　H…Relative humidity.
E…Evaporation from atmometer.
A…Cane absorption.

**（4）數種植物之吸水在日蝕間的變化及吸水遲延時間之變異原因**

於日蝕時觀測吸水之變化情形，爲研究吸水與外界因子關係的最好機會。上面曾述及甘蔗、玉蜀黍及香蕉等植物，於晴天，其吸水之變化過程爲一單頭曲線。但於日蝕日，其變化情形迥然有異。即一般植物若遇日蝕時，其吸水乃隨日蝕之進行而呈急劇之變化，結果吸水之變化曲線變爲双頭曲線（參閱圖 6,7,8）。關於日蝕對於吸水之影響，玉井氏（13）曾於1941年9月21日（98.8%），以甘蔗爲材料，於臺北作過觀察試驗，並報告甘蔗吸水受日蝕之影響極顯著。筆者亦於1948年5月9日（86%）於臺中以甘蔗作相同觀察，結果與玉井氏之測定結果頗相類以（圖6）（13, 14）。以後筆者（29）復於1955年6月20日（76%），在屏東以玉蜀黍作同樣的觀察（圖7），所獲結果亦與甘蔗之情形趨於一致。因上述二次日蝕均發生於中午後，故極適於植物吸水之研究。當日蝕開始之際，植物之吸水已接近最高點，故隨日蝕之進行，吸水急速減少而至蝕甚時達於最低點，次後復隨日蝕之復圓而迅速增加。在日蝕期間，吸水減少趨勢，二次測定結果幾乎一致（參照表5）。由此可知甘蔗與玉蜀黍吸水特性極相似，實感有興緻。

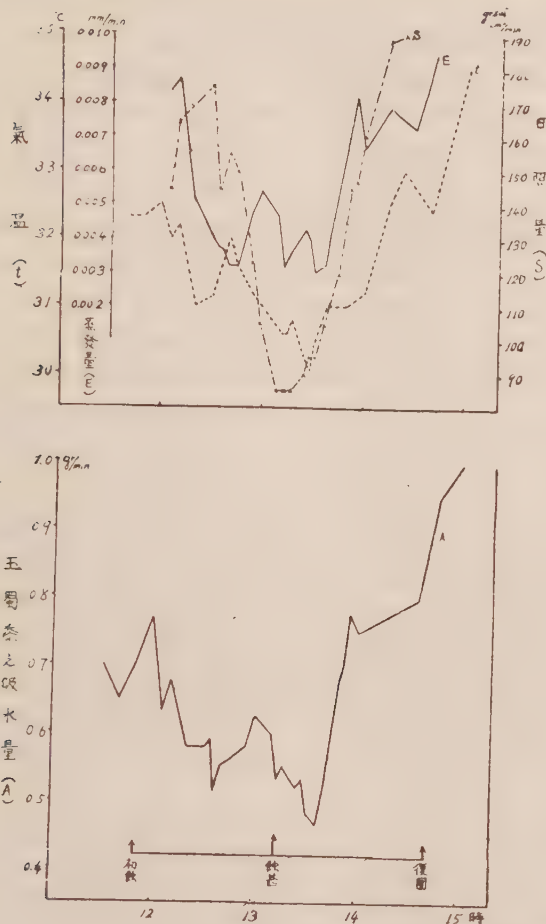



圖7. 1955年6月20日於屏東日蝕時玉蜀黍吸水量與外界因子之日間變化

Figure 7. Graphs showing the relation between the absorption of water each hour in Corn plant and its enviromental factors observed at Pingtung during the few hours of solar eclipse occurred on June 20, 1955.

S…Solar radiation.

E…Evaporation from porous cup.

t…Air temperature.

A…Water absorption in Corn plant.

表5. 日蝕時數種植物吸水量變化程度之比較

Table 5. Comparison of fluctuation degrees in the absorption of water in several plants during the course of solar eclipse (absorbing amount g/min.).

| 植物 Plant | 初蝕時 At the beginning of solar eclipse. | 蝕甚時附近之最低值或最高值 Min. or Max. value obtained near the climax phase of solar eclipse. | 復圓時 At the end of solar eclipse. | 蝕分 Eclipse degree. | 備註 Remarks |
|---|---|---|---|---|---|
| 甘蔗 Sugar Cane | 0.434 (100%) | 0.289 (66%) | 0.468 (107%) | 86% | May 9,1948 (observed at Taichung) |
| 玉蜀黍 Corn | 0.700 (100%) | 0.466 (66%) | 0.750 (107%) | 76% | June 20, 1955 (observed at Pintung) |
| 含羞草 Mimosa Pudica | 0.067 (100%) | 0.033 ( 49%) | 0.047 ( 70%) | 94% | Apr 19, 1958 (observed at Taichung) |
| 虎耳草 Saxifrage | 0.048 (100%) | 0.063 (131%) | 0.024 ( 50%) | | |
| 仙人掌 Cactus | 0.050 (100%) | 0.250 (500%) | 0.067 (134%) | | |
| 落地生根 Bryophyllum | 0.019 (100%) | 0.083 (436%) | 0.050 (263%) | | |

其次日蝕時吸水量呈現最低值之時刻，據測定結果均在蝕甚以後，惟遲延時間迥異。據玉井氏於臺北之觀測，甘蔗吸水量最低值呈現時刻在蝕甚後28分，吳氏（30）在臺中以甘藷觀測之結果爲蝕甚後 8 分，筆者於臺中以甘蔗觀測之結果爲蝕甚後15分，又在屏東以玉蜀黍觀測之結果爲蝕甚後24分。至於吸水量最低值呈現時間之不同，筆者（29）曾推想除因植物種類不同之原因以外，並認爲測定場所亦爲主要原因之一。因玉井氏係於玻璃室內進行觀察，筆者則係於戶外進行。惟惜無機會求證。後於1958年 4 月19日幸於臺中逢日環蝕（94%），筆者認此乃探究吸水遲延時間不同原因最好機會，特以數種植物作比較觀察，並將植物分別罩以透明玻璃鐘與未罩者兩種測定日蝕對於吸水之影響，獲得罩以頂端有孔透明大玻璃鐘與未罩的同一種植物，其吸水量最低值呈現於蝕甚後之時間廻然有異的結果(參閱圖8及表6)。即罩以玻璃鐘的含羞草，其吸水量最低值呈現於蝕甚後之時間較未罩以玻璃鐘者遲延約10多分鐘。由 Atmometer 之蒸發量亦顯示同一傾向 。由此結果可說明因測定場所（即植物之生長境環）與吸水有密切關係，並暗示此種情形與上項(2)的結果有互相符合之處，饒有興趣。又於蝕甚後，含羞草之吸水及由 atmometer 之蒸發量呈現最低值的時間完全一致，仍暗示着與含羞草於早晨開始吸水的時間較其他植物早的結果有互相符合之處，極富興趣。

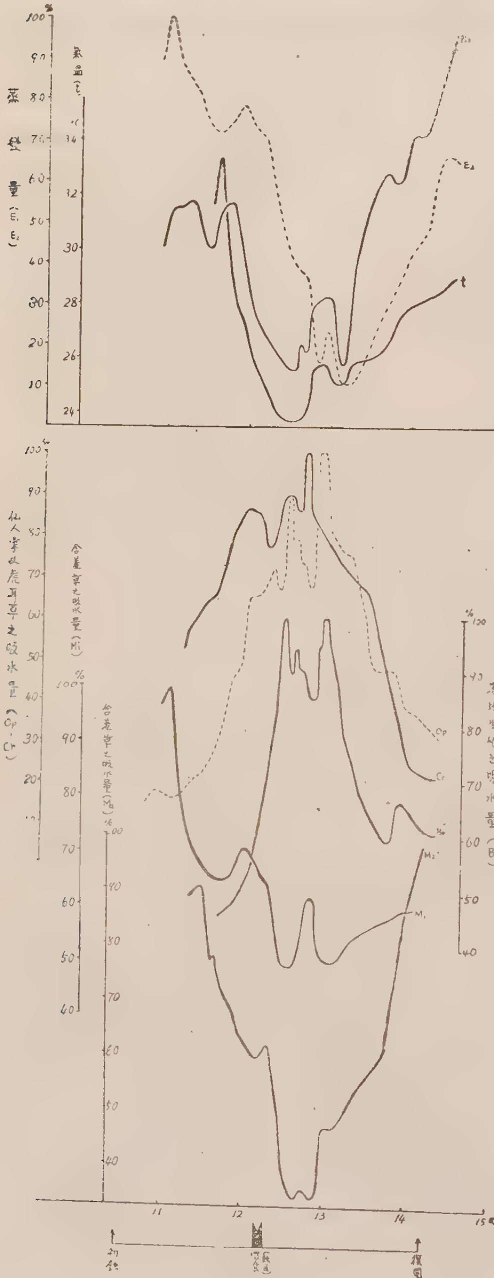


圖8. 1958年 4 月19日於臺中日環蝕時數種植物之吸水作用與外界因子之日間變化

Figure 8. Graphs showing the changes of the absorption of water each hour in some plants and its enviromental factors observed at Taichung during the course of the annular eclipse occurred on Apr 19, 1958.

t…Air temperature.

$E_1$…Evaporation from atmometer.

$E_2$…Evaporation from atmometer (covered with a bell-jar).

Cr…Water absorption in Creeping Saxifrage.

Op…Water absorption in Cactus.

$M_1$…Water absorption in Mimosa Pudica.

$M_2$…Water absorption in Mimosa Pudica (covered with a bell-jar).

表6．1958年4月19日於臺中日環蝕時所觀察數種植物吸水最高値及最低値遲於蝕甚後之時間
Table 6. The time of delay of maximum and minimum water absorption from the climax of annular eclipse, Apr. 19, 1958 (at Taichung)

| 植物 Plant | 吸水最低値遲於蝕甚之時間① | | 吸水最高値遲於蝕甚之時間② |
|---|---|---|---|
| | 罩玻璃鐘③ | 未罩玻璃鐘④ | |
| 含羞草 Mimosa Pudica | 29′—36′ | 12′—17′ | — |
| 仙人掌 Cactus | — | — | 35′—41′ |
| 落地生根 Bryophyllum | — | — | 21′—24′ |
| 虎耳草 Saxifrage | — | — | 27′—29′ |
| 蒸發量 Evaporation from atmometer | 32′—36′ | 14′—18′ | — |

1....Time of delay of minimum water absorption from the climax of annular eclipse.
2....Time of delay of maximum water absorption from the climax of annular eclipse.
3....Covered with a bell-jar.
4....Normal.

其次如仙人掌、落地生根及虎耳草等，其吸水對於日照顯示負反應之植物，於日蝕時呈現恰與上述者相反趨勢。此等植物外觀上似較反應遲鈍，但於日蝕期間對於光度之減少呈現極銳敏的反應，實値得特別注意。在此等植物，其吸水隨日蝕之進行而急速增加，並於蝕甚附近呈現最高値，次後則隨太陽復圓而迅速減少（參閱圖8）。至於日蝕期間，吸水現出最高値的時刻均遲於蝕甚，但因植物之不同，遲於蝕甚之時間廻然有異。如仙人掌之吸水呈現最高値的時間遲於蝕甚最久，發生於蝕甚後35～41分，落地生根最早，時間爲蝕甚後21～24分，而虎耳草即位於兩者之間，約於蝕甚後27～29分。因此次爲日環蝕，而蝕甚時間較長，故各種植物於蝕甚前後呈現吸水最高値或最低値之時間亦因此而延長，此與以往者不同。由上可知植物之吸水與外界因子間之關係至爲密切。各種植物在日蝕期間之吸水情形雖具有同一傾向，但均具區域的特性，極富興趣。

**（5）地上部對於根吸水之影響**

（a）遮光對於吸水之影响

爲明瞭地上部對於根吸水作用之影響，筆者曾以香焦爲材料進行試驗。圖9爲香焦之吸水因其地上部受遮光處理後發生之變化情形。由此可知香焦之地上部受遮光處理後，其吸水雖減少，但減少速度極緩慢，且除去遮光用黑袋後，其吸水雖復趨於增加，但其速度亦極緩慢。在進行遮光處理過程中，經遮光處理後其吸水減少之程度亦極不顯著，其變化曲線的底部呈平面狀。此種傾向與玉井氏(16)以甘蔗觀測的結果完全不同。又經遮光處理後，香焦吸水減少的比率經兩次測定結果約爲未處理前之50%，相當於黃昏時之吸水量。

（b）葉身的狀態與吸水作用

葉爲蒸散作用的主要器官。以蒸散作用作爲被動吸水之原動力時，凡影响蒸散作用的因子料

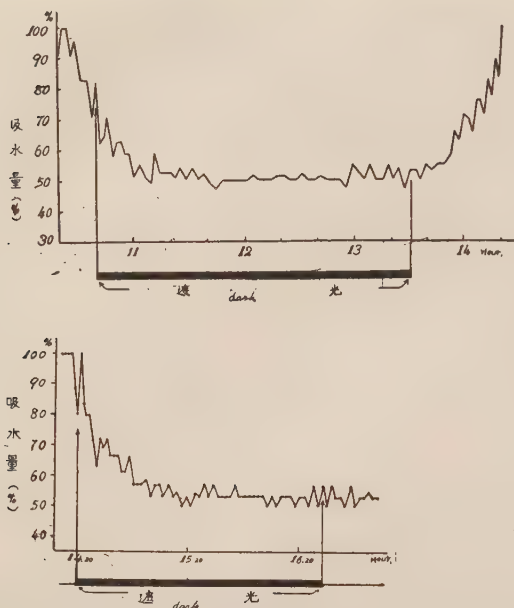



圖9. 遮光對香蕉吸水作用之影響

Figure 9. Influence on daily changes of water absorption after the above-ground Parts of Banana was shut out from light.

必可影响根之吸水作用。玆爲明瞭葉片的狀態對於吸水之影响情形，特以刀片，沿着葉脉，將葉片切成細片狀，並依連續記錄法得處理前後之吸水變化過程如圖10及表 7 。由此表可獲知經破葉處理後，香蕉之吸水稍有增加趨勢。如此顯示香蕉之葉部如遭其他機械作用，葉片破碎呈細片狀時，其吸水較正常時略有增加可能，實値得注意。

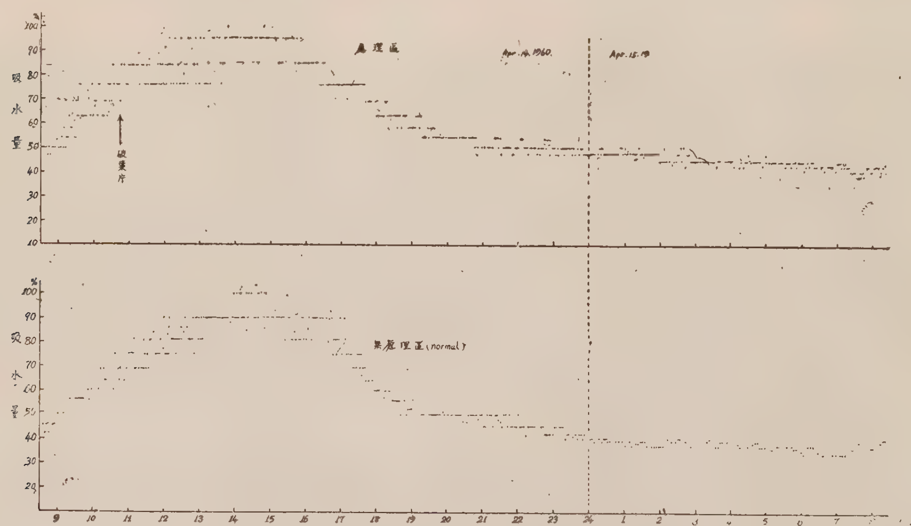



圖10, 破葉片對香蕉吸水作用之影響

Figure 10. Influence of spliting leaves( ↑ ) to the daily changes of water absorption of Banana plant.

表7. 破葉、折彎葉柄及切除葉片對香蕉吸水之影响

Table 7. Influence of spliting, bending and removing of leaves on water absorption of Banana plant.

| 日 期 Date | 區 別 Plot | 處 理 種 類 Kind of treatments | 吸 水 量 Amount of water absorption (cc) | 比 數 Relative value (%) |
|---|---|---|---|---|
| Apr. 13, 1960 | Banana. A | CK | 1315 | 100 |
| | Banana. B | Normal | 914 | 100 |
| 〃 14, 〃 | Banana. A | CK | 1305 | 99.1 |
| | Banana. B | Splited leaves | 910 | 99.6 |
| 〃 15, 〃 | Banana. A | CK | 1282 | 97.4 |
| | Banana. B | Bended leaves | 790 | 86.4 |
| 〃 16, 〃 | Banana. A | CK | 1012 | 77.4 |
| | Banana. B | All of the leaves was removed except the main nerve | 583 | 63.7 |
| 〃 17, 〃 | Banana. A | CK | 904 | 68.7 |
| | Banana. B | A day after the leaves removed | 427 | 46.7 |

（c）折彎葉柄、切除葉片及切除地上部對於吸水之影响

進一步研究葉部對於吸水之影响，曾於進行破壞葉片處理次日，將所有葉片於葉柄基部折彎，並爲避免所得吸水量包括受氣候因子之影響而發生之數值在內，曾與未處理植株作比較觀察，以證實處理後實際發生的變化，所得結果如表7及圖11。經折彎葉柄處理後，吸水約減少14%。惟全日中其吸水之變化，尙無顯著差異。據玉井氏（16）的研究，甘蔗全葉數之⅓被折彎後，於次日，其吸水量減少爲未處理前之51%，可知折葉處理對於香蕉吸水之影響遠不如甘蔗爲顯著。此兩種植物顯示各具不同之特性。

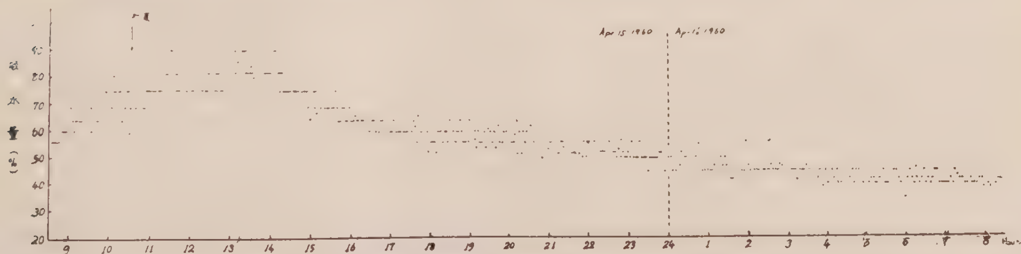



圖11. 折葉後香蕉吸水作用在一日中之變化情形

Figure 11. Daily changes of water absorption when Banana leaves were bended artificially (↓).

但若將葉片切除，吸水則迅速減少。即沿主脈兩側將葉片切除後，香蕉之吸水立即發生變化（參閱圖12），而吸水量減少爲未切除葉片前之50%。惟經若干時間後，吸水量復趨增加，致使吸水變化曲線變爲双頭曲線，且吸水最高値呈現時間亦因此而延緩至黃昏入夜前（圖12）。惟因吸水於黃昏後復趨於增加，故一天總吸水量之減少率縮小，實値得吾人注意。

綜合以上所得結果，可推測香蕉根之積極的吸水具有重大作用。在事實上，若將香蕉之地上部，於莖基部切除，其吸水之變化趨勢與切除葉片之場合相同（參閱圖13）。即其莖部被切除後

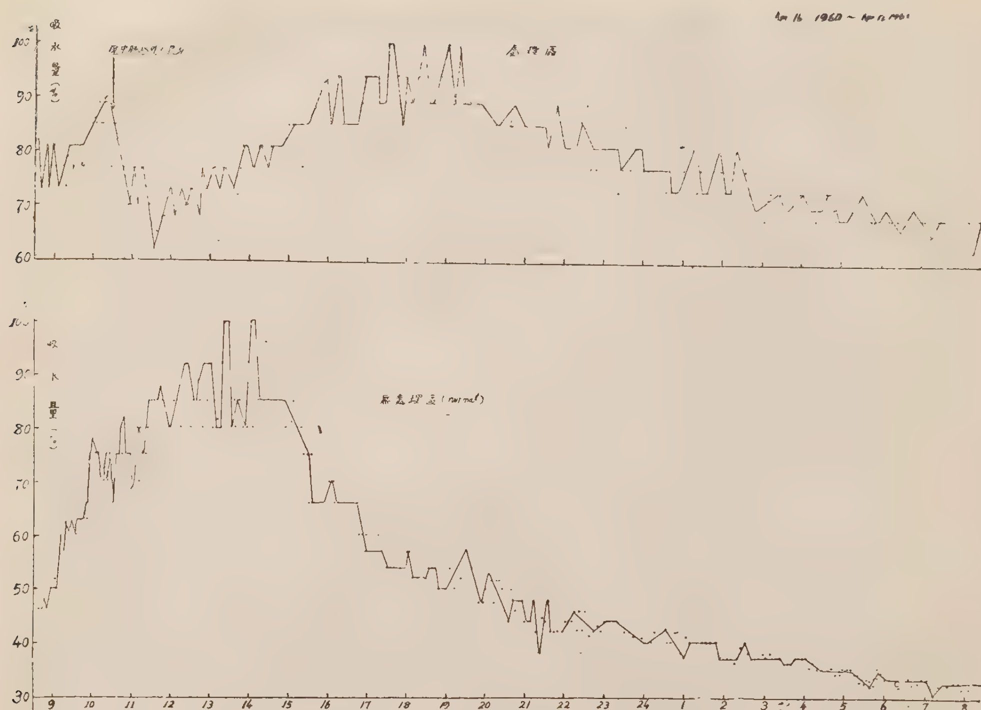



圖12.　刈除葉片對香蕉吸水作用之影響

Figure 12.　Influence of removal of leaves ( ↓ ) on Banana plant to its daily change of water absorption.

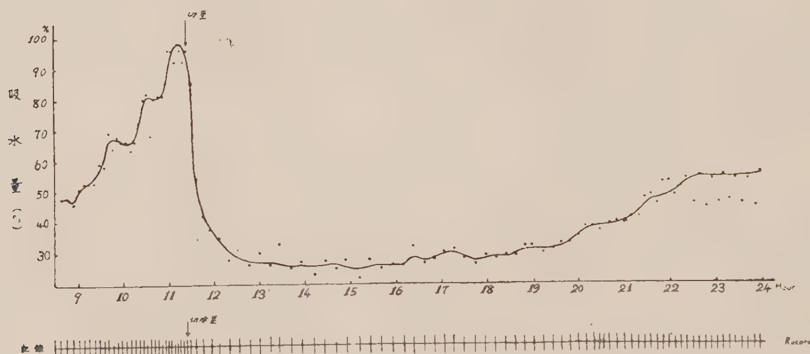



圖13.　刈除假莖後香蕉吸水作用之變化情形

Figure 13.　Daily change of water absorption of Banana of which stem was removed ( ↓ )

，雖吸水即時減少，但仍不完全停止，而吸水量亦僅減爲未切除前同一時間之吸水量的⅓，且於入夜前復趨增加。又經切莖後，由切口溢出之水液量分別於日間與夜間所測得數量如表 8 。於表 8 所示的結果似可爲香蕉之積極的吸水顯具重大意義及爲吸水復趨增加之依據，實具研究之必要性。

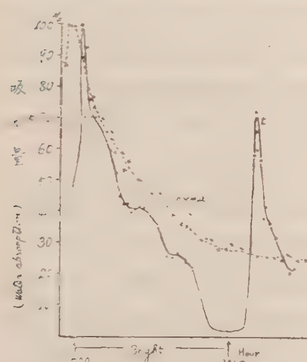
表8. 香蕉之溢液量

Table 8. The amount of bleeding on cut end of Banana plant.
(The amount of bleeding from the cut end was examined after the above-ground part was removed from Banana plant.)

| | 時間 Time | 溢液量 Bleeding (cc) |
|---|---|---|
| 切莖後第一天 One day after the cut. | 9:00——20:00 | 185 |
| | 20:00——8:30 | 70 |
| 切莖後第二天 Two days after the cut. | 8:30——20:30 | 70 |
| | 20:30——8:30 | 60 |
| 切莖後第三天 Three days after the cut. | 8:30——20:30 | 55 |

(6) **夜間照明對於落地生根吸水之影響**

上面曾敍述落地生根之吸水與日照成負相關。該植物於晝間，光度强時即停止吸收水分，而至黃昏前始復行吸水。吸水最盛期在入夜前後，以後復趨減少。筆者爲明瞭落地生根之吸水與光之關係，曾於黃昏後不同時間以 250W 白色光自距植物體 20 公分處行照光，並觀察落地生根之吸水作用經照光後所發生之變化，結果如圖14。惟照光時間於黃昏前時，須經相當的時間後吸水始發生變化。如在黃昏後照光，誘致吸水發生變化所需照光時間縮短。又如於入夜後照光，吸水即時發生變化。此結果似顯示落地生根於入夜前後一段時間，其吸水極爲穩定，不易受照光之影響。故於黃昏前照光與於入夜後照光對於落地生根吸水之影響常發生於同一時刻，饒有趣意。又經熄燈後，不分照光時間之早晚，吸水均迅速增加，但不久復趨減少，因此吸水之變化曲線成爲双尖頭曲線。



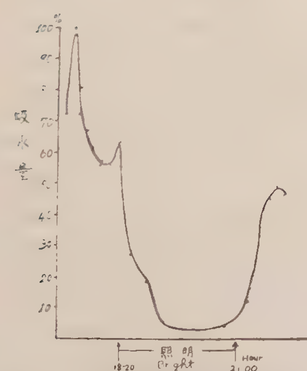




圖14. 夜間照明對落地生根吸水作用之影響

Figure 14. Influence of illumination on water absorption of Bryophyllum.

## 四 討論

植物之生理作用與外界因子之關係至爲密切，筆者爲探討外界因子對植物吸水之影響。十餘年來，利用自動灌水裝置栽培植物，並自行附加毛細管裝置，測定吸水在日間之變化情形。獲悉甘蔗及玉蜀黍之吸水，受外界因子之影響極顯著。惟以往之實驗，缺少多種植物之比較。關於低溫、測定場所及地上部之狀態等與吸水之關係，未見具體報導。筆者有鑑及於此，除部分利用毛細管測定吸水在日間之變化外，並藉自製吸水電動記錄計，進行記錄數種植物在一日間之吸水變化，以便測定比較，並觀察不同植物之特性。又對香蕉作下列四種處理(1)破葉片，(2)折彎葉柄，(3)去掉葉片及(4)切除地上部後再行吸水之測定，擬由此等試驗以求瞭解當根吸收水分時，其地上部所具有的意義，其所得結果已詳述於上面。

在平常日，藉毛細管中之水頭移動速度所測得甘蔗及玉蜀黍之吸水；在早晨日出後，隨氣溫之上昇及蒸發量之增加而迅速增多。其最高吸水量呈現時間常與氣溫及蒸發量之最高時刻

吻合，此種測定結果完全與煙草（28）、香瓜（21）及柑桔類（16.17.18.19）之測定結果吻合。在一日中，吸水時刻受此等氣候因子之影響，其現象至爲顯著。惟此等因子中，據以往之測定（14.15），蒸發量與吸水間之相關較氣溫爲高而安定。植物之蒸散作用酷似蒸發作用，且吸水作用中，基因於蒸散作用之被動吸水爲植物之主要水分吸收（1.2.4.5.16）。本文藉自製電動記錄計所獲得蒸發量在一日中之變化情形，顯示更與吸水之變化情形趨於一致。

據電動吸水記錄計獲悉；甘蔗、香蕉及含羞草等植物之吸水，在一日間之變化情形極相似。惟各種植物開始吸水時間顯然有異：香蕉爲上午八時左右，含羞草爲上午五時左右，甘蔗爲上午七時左右。至日間，吸水之最高點及吸水最盛期的期間亦均有差異，顯示此三種植物對日照變化之反應不同。尤其是含羞草，開始吸水增加的時間特早，這暗示着此植物之地上部對散光之反應極爲敏感。這似乎與該植物之睡眠運動有密切關係，實富有興趣。

在同一環境下測得仙人掌之吸水現象；上午日光較强時幾乎或完全停止。此結果與Kramer氏（1）及玉井氏（17）之測定結果符合。但在日間停止吸水期間及黃昏前復行吸水後之增加趨勢顯有不同：據筆者測定，在黃昏前恢復吸水後，增加吸水的速度極迅速，此與玉井氏所測定以較緩慢增加之情形不同，且在日間，吸水最低値呈現時間亦略有差異。由玉井氏測定之結果推想，仙人掌吸水最低値呈現時間約在上午10時左右，但筆者則爲13～15時，然不論時間有何不同，仙人掌之吸水對日照呈負反應則是一致的，亦顯示着仙人掌之吸水，對於日照的反應很敏感，同時在一日間吸水之變化亦極顯著，實値注意。

落地生根及虎耳草爲二種吸水之變化情形與仙人掌相似的植物，但兩者吸水最盛時刻則略有不同：仙人掌吸水最盛時刻約在19時左右，落地生根則約在17時以前。至於吸水最低時刻頗一致。但落地生根之吸水最低時刻，曲線底部較狹短，並於夜間之變化情形亦有差別，可知兩者各有顯然區別的特性。

上述仙人掌吸水最少時刻，玉井氏與筆者之測定不一致，此可能由於實驗場所及測定條件不同，因玉井氏在日本所測定者，筆者係在臺灣測定，頗難比較。但測定場所不同對於吸水是否有影響？筆者藉吸水電動記錄法，分別置於玻璃室內與室外的二株香蕉，在同一時間測定各株之吸水在一日間之變化情形，獲悉兩者之吸水情形實有明顯不同：戶外者吸水變化較顯著，此可能因戶外的外界因子的變化較玻璃室內爲大所致。由此可知，吸水在一日間之變化情形與測定場所有密切關係，實値重視。

植物一日之吸水量與當天之氣候有密切關係。香蕉及甘蔗在雨天之吸水量僅爲晴天之數分之一。但吸水量與天氣之關係，視測定場所不同而有莫大變化。如陰天，玻璃室內植物之吸水量減少程度較戶外區爲著，雨天則情形相反。至於雨天之吸水作用，筆者藉電動記錄計所得結果，祇要能防止雨水流進土壤中，在雨天由 Atmometer 之蒸發雖已停止，但香蕉仍以極大速度繼續進行吸水。這種在雨天裏之吸水現象，當設計灌漑水量時似應加以考慮。

植物一日之吸水量，尙受當天氣溫高低之影響。在低溫情形下，香蕉吸水作用顯著受阻，而對外界因子之反應亦不如正常時敏感，致使吸水作用在日中變化極不顯明。即吸水在一日間之變化曲線無有顯著的起伏現象，可知氣溫爲影響吸水之一重要因子。當筆者整理本文時，蒙玉井博士贈寄利用 Growth cabinet 所完成氣溫對吸水影響之研究報告（22,23）。該報告顯示氣溫自 25°C 降至 10°C 時，夏柑之吸水消失對於光之反應，但經一段時間後，又漸次恢復吸水能力，此結果與筆者在自然條件下測得的結果完全一致。如此吸水因氣溫之降低而受阻礙，將容易導致植物體內之水分代謝失常。據玉井氏之研究，夏季時，在 10°C 的 Growth cabinet 中之水稻及夏柑之吸水，日中變化完全消失，但蒸散作用之日中變化仍然極顯著。可知低溫影響吸水及蒸散作用之情形廻然有異。田川氏（5,24）就菜豆之測定結果亦如此。筆者之測定結果亦完全

相同（表４）。在適當溫度情形下，香蕉之吸水量殆與蒸散量相等。但在低溫情形下，因吸水作用受低溫之影響較蒸散作用所受之影響爲顯著，如此乃導致植物體內水分收支現象趨於不均衡，而致使植物發生缺水現象。在臺灣中南部，冬季爲乾燥期，上述現象，應予充分考慮。

日蝕爲研究植物吸水與外界因子之關係最好機會。筆者分別在三次不同日蝕所獲吸水之變化情形，雖三次日蝕之蝕分各有不同，但結果却幾乎一致。甘蔗、玉蜀黍及含羞草，其吸水隨日蝕進行程度而減少，並於蝕甚後達最低點，次後則隨太陽之復圓而漸次增加。惟吸水最低值呈現於蝕甚後之時間各有不同。此種遲延時間之不同，筆者認爲除與植物種類有關外，測定場所之狀況不同亦爲可能原因之一。爲明瞭實情，曾於第三次日蝕時（1958年４月19日），以透明玻璃鐘罩於植物地上部，並與無罩者作比較觀察，獲悉兩者吸水遲延於蝕甚後之時間不同。可知於日蝕時，植物吸水最低值呈現時間確與測定條件（生長環境）有關。此種傾向完全與平常日之情形一致，實覺有興趣。

又於日蝕時所獲含羞草之吸水最低值呈現時間幾乎與 Atmometer 蒸發量最低值呈現時間一致，可知該植物地上部對於外界因子變化之反應最敏感，此與該植物於早晨開始吸水增加最早的趨勢互相連貫，頗有意味。

吸水對於日光呈負反應之植物，在日蝕時之變化情形恰與甘蔗、玉蜀黍及含羞草等相反。即隨蝕分之加深，吸水速率增加，並以蝕甚爲界限，次後隨太陽之復圓而迅速減少。惟吸水最高值呈現時間亦遲於蝕甚，此種傾向與甘蔗及玉蜀黍等之情形相同。仙人掌、落地生根及虎耳草等三種植物中，落地生根之吸水最高值呈現時間最早，仙人掌最遲而虎耳草則位於兩者之間。此種差異，似因地上部對日光之反應各有不同所致。至於日蝕時，吸水趨於增加的原因，須待日後之研究。

據玉井氏（16）之研究，甘蔗之吸水受折葉及切除葉片之影響極顯著。折彎全葉數三分之一的葉片時，甘蔗之吸水急劇減少。至處理之次日，吸水量減爲未處理前之51％。若將全部葉片切除，吸水則減爲未切除以前之1/10以下。可知被動吸水佔着甘蔗全吸水量之大部分。筆者亦以香蕉爲試驗材料進行⑴遮光，⑵破葉，⑶折彎叶柄基部，⑷切除葉片及⑸切除莖部等處理，所獲結果略與玉井氏者不同。香蕉，以黑紙袋遮光後，吸水雖減少，但減少程度不甚顯著，且曲線底部成爲平底狀，此似暗示着其吸水具有與甘蔗完全不同的特性。此種性質亦可能爲陰天時，香蕉吸水之減少程度較甘蔗爲少的原因，頗有意味。又若將葉片撕成細片狀，其吸水略見增加，此似暗示着其廣大葉片受機械傷害後，吸水反有增加的可能。此點在管理上極值注意。

折彎葉柄基部後，香蕉之吸水雖受阻害，但亦不甚顯著。若將葉片切除，吸水迅速減少至未切除前之1/2左右，然經若干時間後，吸水復趨增加，故吸水之變化曲線與平日者廻異，且吸水最高時刻亦因此而展延至黃昏（參閱圖12）。又若將地上部切除，吸水亦不完全停止，僅減爲未處理前同一時間之吸水量的1/3，且於入夜前復趨增加。此似因根行積極的吸水作用所致。綜觀上述結果，可知香蕉根之積極的吸水作用具有重大意義，並可能爲其葉片被切除後吸水所受影響不甚顯著之原因。實感有興趣。

最後關於夜間照明對於落地生根吸水之影響，據本實驗，入夜後行電燈照明時，落地生根之吸水顯著受阻害，但若照明時期在吸水剛開始時，引起吸水發生變化所需照明時間延長。但停止照明後，因吸水一度急激增加，然後復趨減少，致使吸水之變化成爲双銳頭曲線。如此夜間照明，對吸水有阻礙，但停止照明後，因阻礙吸水之原因消失，乃導致吸水一時的促進現象。其原因須待日後進一步之研究。

## 五　摘　　要

爲探討氣溫之高低，測定場所，地上部之狀態等條件對植物吸水之影響，及觀察日蝕時，對不同植物之吸水變化情形，乃利用自動灌水裝置，並附設毛細管測定管內水頭移動速度及自製吸水電動記錄計進行比較測定，獲得頗與趣的結果，玆摘要所得結果於下。

1.　早晨日出後，植物吸水之變化隨着而顯著進行。但對氣候因子之反應，則因植物種類之不同而異。即各植物均有顯然區別的特性（圖2,10）。

2.　早晨開始吸水的時間，以含羞草最早，香蕉最遲，甘蔗位於兩者之間，顯示植物地上部對於散光之反應迥然有差異（表1）。

3.　關於吸水對日光成負相關的植物，除前實驗仙人掌外，本文另加兩種新例子，落地生根及虎耳草（圖3及8）。

4.　一日之吸水量隨天氣之好壞而發生差異（表3）。但又因測定場所不同而有很大變化。如在陰天，玻璃室內香蕉之吸水量僅爲晴天之60%，但戶外香蕉約佔90%，此可能爲外界因子之變化情形不同所致。

5.　在適當溫度情形下，香蕉吸水量殆與蒸散量相等。但在低溫情形下，因吸水作用受低溫之影響較蒸散作用爲顯著，故產生吸水量與蒸散量不均衡現象，致使植物發生缺水然現（表4）。

6.　在日蝕時，甘蔗、玉蜀黍及含羞草等植物之吸水隨日蝕之進行而減少。其吸水最低値呈現於蝕甚之後。此現象除因植物種類不同外，尙因地上部之狀況不同而發生差異，即雖同一植物，若生長環境不同，吸水遲延於蝕甚之時間各異。

7.　仙人掌、落地生根及虎耳草之吸水，在日蝕期間之變化情形恰與甘蔗、玉蜀黍等相反。隨日蝕之進行，其吸水迅速增加。吸水最高點亦呈現於蝕甚之後，此現象與前者相同（圖8及表6）。

8.　香蕉之地上部被遮光後，吸水雖減少，但不如甘蔗顯著（表7）。

9.　以刀片沿着側葉脉，將香蕉之葉片切成細片狀時，其吸水較正常時略有增加。

10.　香蕉之吸水作用，經折彎葉柄處理後，吸水量約減少14%，惟吸水在日中之變化情形尙無顯著差異。

11.　香蕉之葉片被切除後，吸水迅速減少，且僅爲平常日之約½，但經一段時間後，吸水復趨增加，吸水之變化曲線因而變爲双頭曲線。

12.　若切除香蕉之莖部，吸水減至未處理前同一時間之⅓（圖13）。

13.　切除莖後，除當天之溢液量較多外，日間及夜間之差異不明顯（表8）。

14.　吸水對日光呈負反應的落地生根，在夜間受照明之影響而減少，惟在剛開始吸水時，照明之影響不明顯。又停止照明後，因吸水一時急劇增加，致使吸水之變化成爲双銳頭曲線（圖14）。

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# A Study on the Water Absorption Characteristics in Some Plants

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## Summary

Satisfactory understanding of the water consumption characteristics of plants may provide not only an important means of studying the characteristics of water absorption of plant but also giving an essential references for rationalization of water management of crop produotion.

From this viewpoint, the author has studied (1) the influences of weather, air temperature, location, and solar eclipse on water absorption of plants and (2) the role of above-ground parts of plants on water absorption, by means of measuring with the capillary tube attached on autoirrigator and self-designed electric, water absorption recorder (the lower diagram in Fig. 1).

The following are the summarized results obtained through the studies.

1. Significant change on water absorption was observed soon after the sunrise. There was a wide variation in the reaction of above-ground parts of different plants to the change of weather (Fig. 2).
2. The time of starting water absorption in early morning was different for the different kinds of plant; Mimosa Pudica was earlist, Banana was the latest, and Sugar Cane was about intermediate (Table 1).
3. Besides Cactus, two plants, Creeping Saxifrage and Bryophyllum were added to the list of plants which react negatively to water absorption (Fig. 3& 8).
4. The amount of water absorption per day was influenced greatly by weather and also by the location (Table 2 & 3).
5. The low temperature (about 8°C-15°C) had a great effect on water economy in Banana plant; water absorption and transpiration decreased heavily, and the daily change in water absorption nearly disappeared (Fig. 5). It was considered that such confusion of water economy at low temperature was caused by the difference of response to low temperature between water absorption and transpiration (Table 4).
6. The amount of water absorption of Sugar Cane, Corn, and Mimosa Pudica were decreased to a great extent in direct proportion to the progress of solar eclipse (Fig. 6, 7, 8). The results observed in three experiments confirm that the minimum water absorption takes place later than the climax of the

solar eclipse. The amount of delay is dependent upon the kind of plant and also is influenced by the location (Table 6).

7. The water absorption of Cactus, Creeping Saxifrage, and Bryophyllum were increased sharply in proportion to the progress of solar eclipse. The results observed at Taichung during the solar eclipse (eclipse degree 94%), showed the time of the maximum amount of water absorption to be a little later than the climax of solar eclipse. The amount of delay is depending upon the different kinds of plants (Fig. 8, Table 6).

8. Decreased water absorption was observed soon after the abov-ground part of Banana was shut out from light. The degree of decrease was approximately half of that under normal conditions (Fig. 9).

9. A slight increase of water absorption was observed when the Banana leaves were split into small pieces (Fig. 10, Table 7).

10. Water absorption of Banana on which leaves were broken artificially, showed no difference from that of normal plant (Fig. 11, Table 7).

11. When all of the leaves were removed except the main nerve, the water absorption was soon dropped about 40%, then was increased gradually and reached its maximum in the evening (Fig. 12).

12. When the above-ground part was removed oompletely, the water absorption of Banana decreased suddenly to approximately 30% of the untreated plant. Then, several hours later, began increasing again (Fig.13).

13. The amount of bleeding from the cut ends was examined after the entire above-ground part was removed from Banana plant. The bleeding was extremely high immediately after the removal, but no significant difference was observed on the amount of bleeding in day and night time (Table 8).

14. The water absorption decreased when the plant of Bryophyllum, on which light has a negative effect on the water absorption was illuminated at night (Fig. 14). But, If the illumination was given soon after the measurable water absorption started in evening, the occrrence of light effect was delayed significantly.

# 用電氣泳動法分離獨居石中各種稀有土金屬元素之研究(註)

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## 引　　言

臺灣海灘，河溪，砂礫地帶均蘊有獨居石礦，而獨居石之主要成份爲稀土族元素 (Rare earth element) 之磷酸鹽及不定量之釷和鈾等。有時氧化釷 ($ThO_2$) 之含量可高達 10 %，氧化鈾 ($U_3O_8$) 亦有達1%者，其主要成份之含量如下(1)：

| $Tho_2$ | $Ce_2O_3$ | $La_2O_3$ 等 | $y_2O_3$ 等 |
|---|---|---|---|
| 4—10% | 28—33% | 24—30% | 1—4% |

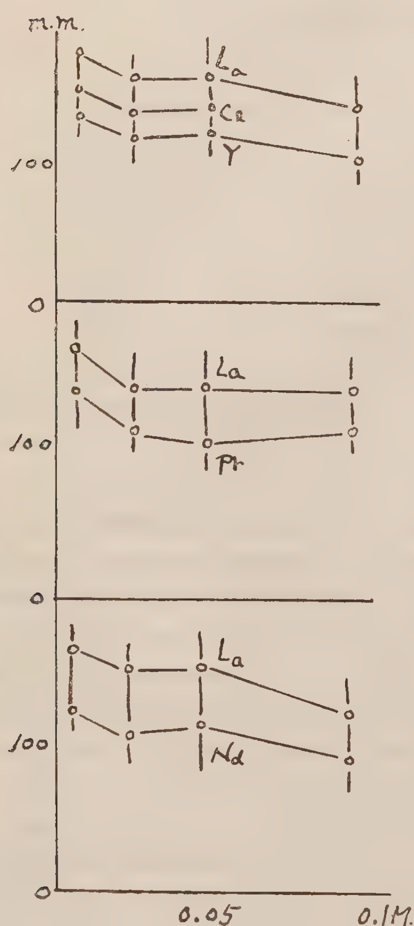
此種礦石通常爲黃色，紅棕色，乃至褐色，自半透明至不透明狀，有松香光澤，比重自 4.9 至5.3，硬度自5.0至5.5 (Moh) ，性脆弱，具弱磁性，常與類似之礦物伴存，(如臺灣獨居石礦，最先在花蓮海灘發現者，即與鋯礦共存(2)) 。

獨居石一向爲釷之主要來源，其中所含之釷及其他多種稀稀有土金屬元素如鈰 (Cerium)，鑭 (Lanthanum)，釹 (Neodymium) 等均爲工業原料，加之釷在原子能方面的重要地位，遂使獨居石之價值益形增高，其中釷之含量達 5% 以上者即爲工業界所重視，然因稀土族元素性質相近，分離頗爲不易，故以純化學方法完全分離此等元素尙有若干困難，過去雖曾有人將此等礦石中各元素之分離作各方面之探討， 利用有機或無機試劑於適當之酸度或以其容解度之不同，使釷先沉澱而與其他元素分離者 ，如焦磷酸鹽 (pyro-phosphate method) (3) 法 ，碘酸鉀 (potassium iodate method) (4)法，環六甲胺 (hexamine method) (5)法，離子交換樹脂 (ion exchange resins method) (6)法等，方法甚多，結果亦稱滿意，然因其手續繁複，操作不易，且提取率純度等未盡臻於理想，故尙有進一步探討之必要。

電氣泳動法的創始者爲 Lodge 氏 (1886) ，其後經過多人之改良，至 1944 年 Consden, Gordon, Martin 利用濾紙爲緩衝液之保持體，行電氣泳動而將胺酸分離，濾紙電氣泳動法遂爲學者競相採用，以分離各種性質相近之物質，如各種抗生素、蛋白質、胺基酸等的分離，在醫藥上及生物化學上皆有良好的成績。Lederer,(7)(8),仲野(9)、皆曾在無機物 (Cu, Hg, Pb, Ca, Au, Pt 及其他普通無機離子) 之分離上有所建樹，牧，安永等(10)以 Citric acid-NaCl 溶液爲分散液，將 Y. La. Ce. Pr. 及 Nd 等稀土元素之混合物予以分離， Takuya R. Sato 等(11)更以 lactic acid 爲分散液將 Nd. Sc 自其他稀土元素中完全分離。本實驗乃鑑於此，用濾紙電氣泳動法分離台產獨居石中之釷及各種稀有土金屬元素，茲就牧及 Takuya 等之試驗結果予以檢討，以資借鏡。

註：本文係本人接受國家長期發展科學委員會四十九年度究補助費所提出之研究報告之一。謹乘此刊出之機會向該會敬致謝忱。

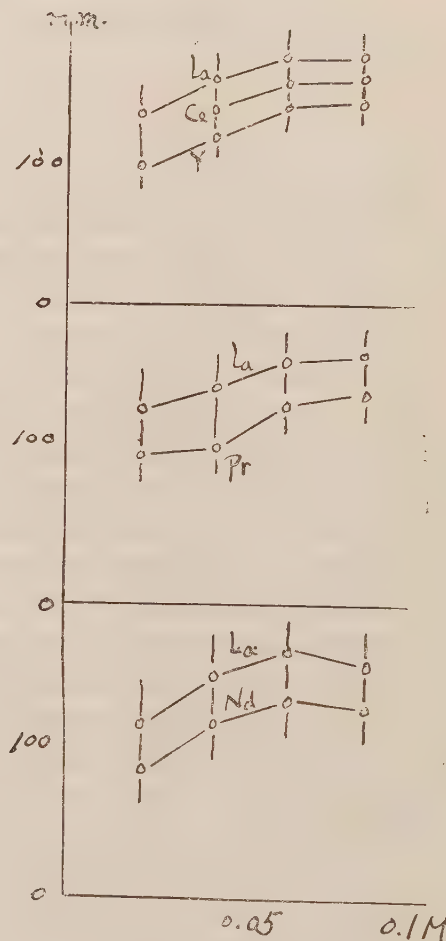
(1) 以 Citric acid-NaCl 之水溶液爲分散液時，檸檬酸之濃度，氯化鈉之濃度，及分散液之 pH 值等，對於泳動分離情形皆有影響，牧⑽曾將分散液中檸檬酸之濃度，氯化鈉之濃度及 pH 值對 Y. La. Ce. Pr. Nd 等五稀土元素分離之影响加以研究，若發見氯化鈉之濃度保持於 0.05 M. 而檸檬酸以 0.006, 0.025, 0.05 0.1 M 不同濃度變化之，則泳動結果如第一圖所示檸檬酸之濃度增大，移動距離多少有變化，然相互間分離狀况則無多大變化。若檸檬酸之濃度定於 0.05 M, 而氯化鈉之濃度以 0.025，0.05，0,075，0.1 M 變化之，則其結果如第二圖所示，氯化鈉濃度增加，各稀土元素之移動距離亦多少增加。




第一圖

檸檬酸濃度對移動距離之影响

(400V. 3hr. 移動，移動之溫度係數爲 2.5%° C.) 。




第二圖

氯化鈉濃度對移動距離之影响

(400V. 3hr. 移動，移動之溫度係數爲 2.5%°C.以 15°C.補正) 。

由上二圖所示可知檸檬酸之濃度在 0.05 M，氯化鈉之濃度亦在 0.05 M 時分離條件最佳，然若將範圍放寬，則檸檬酸與氯化鈉之濃度皆自 0.025 至 0.05 M 爲適當之分離濃度。

pH 之不同對稀土元素分離之影响甚大，於低 pH 時，稀土元素移向陰極，增加 pH 則移動度增加，至 pH 爲 2.8～3.0 時移動之方向改變，再增加 pH 值，向陽極移動之速度亦隨之增加，而最後有達一定值之趨向。

於低 pH 値分離稀土元素無效，但可增加 pH 値而獲得改良，至 pH 等於2.6時最佳。接着移動方向改變後，於 pH 等於$3.0_5$時，分離狀況達最適當處。若再增加 pH 則亦無效果。故分離稀土元素時，宜於 pH 爲2.6或$3.0_5$時行之。

（2） 以 Lactic acid 爲分散液時，乳酸之濃度愈小，分離情況愈佳。乳酸之濃度在 1.5 M 時，除 Sc 外，所有元素皆不分離，酸之濃度小於 0.1 M 時，分離移動甚慢，Sc, 及 Nd 皆可清楚分出。但 Ce, Pm, Pr, 則甚難分離。

基於上兩種情形，本實驗採用兩種分散液；-Citric acid-NaCl, 及 Lactic acid-KCl 以探討其較佳之分離情形。

# 實　驗　部　份

## 一、樣品之處理

### 1. 礦砂之分解：

取經由選礦法分離精純之省產重砂（比重4.98），用瑪瑙乳缽研細至能通過100節孔（Mesh），每次稱取30公分，於蒸發皿中置70 ml 之濃硫酸⑾，⑿，⒀，加熱至200°C.，將稱好之礦砂緩緩加入，不斷攪拌之，保持溫度，於210°C至220°C 之間，加熱四小時，放冷，加入 30 ml 之冰水，充分攪拌，靜置過夜，過濾，濾渣用1:99之硫酸洗滌，至洗液中加氫氧化銨無沉澱產生爲止，棄去濾渣，合併濾液及洗液，以1:99之硫酸配成 850 ml，即得釷，稀土金屬及其他元素之混合硫酸鹽溶液。

### 2. 釷及稀土金屬之提取：

取上述所得之溶液，微加稀釋，以1N 銨水調節 pH 至1.5⑿，冷至室溫，徐徐加入過量（約兩倍重）之草酸⑿，⒀，至無沉澱繼續生成爲止，充分攪拌，靜置過夜，過濾之，以含 1% $H_2C_2O_4$ 及 0.3n. $H_2SO_4$ 之溶液洗滌，至通出之洗液中不含磷酸根爲止，沉澱烘乾即爲混合草酸鹽，再將此草酸鹽於 500—800°C，灼燒成氧化物即可儲起備用。

### 3. 泳動分析用樣品（Sample）溶液之製備：

稱取上文⑵所得氧化物0.4000公分，加少量 $H_2SO_4$，加熱至無濃重白煙發生爲止。加熱時切勿過猛以免溶液濺出。放冷，加 1:1 $ANO_3$ 並加熱溶解之。若有不溶物存在，則須按上法反覆進行，至完全溶解爲止。

加濃銨水於此溶液中，使釷離子及稀土金屬離子均成氫氧化物沉澱，將此沉澱物於瓷漏斗吸引過濾後，以濃熱之硝酸 0 ml 使沉澱溶入三角瓶中，滴加 3%$H_2O_2$ 使溶液之黃色（$Ce^{4+}$）完全變爲無色（$Ce^{3+}$）爲止，以 $NH_4OH$ 調節 pH 至 1.6 加熱濃縮至 3.0 ml 左右，再調節 pH 至 1.6 是爲供試液。

### 4. 鈰標準溶液之製備：

取純粹草酸鈰置瓷坩鍋中，於500～800°C.之間燒成褐色之氧化鈰，稱取此氧化鈰0.4300公分，加 50 ml 之濃硝酸，加熱溶解之。再以3%之 $H_2O_2$ 脫色，使黃色之四價鈰離子還原爲無色之三價鈰離子，以濃 $NH_4OH$ 調節 pH 至1.6，加熱濃縮，使全容積達 50 ml 爲止，再

調節 pH, 即得 0.05 M 之標準鈰溶液。

5. 釷標準溶液之製備：

稱取 1.8000 公分硝酸釷 $Th(NO_3)_3$，$4H_2O$），以 50 ml $\frac{1}{20}$之硝酸溶解之，以$NH_4OH$調節 pH 至1.6，即得 0.05 M 之標準釷溶液。

## 二、分散液之製備

1. 0.05 M Citric Acid- 0.05 M NaCl.

Citric acid 9.6公分，NaCl 2.8 公分，共溶於蒸餾水中，加 4M $NH_4OH$ 2.5 ml 或 4 ml，稀釋至一公升，是爲 pH 2.6 或 pH 3.0 之分散液。若 pH 不等於 2.6 或 3.0，可以 HCl 或 $NH_4OH$ 調節之。

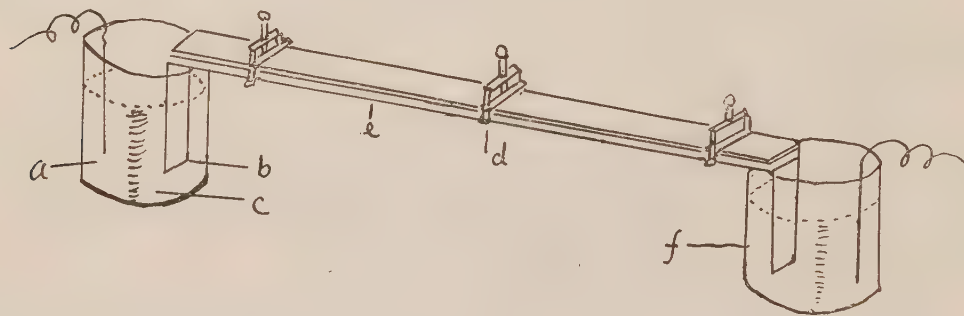
2. 0.1 M Lactic Acid- 0.05 M KCl.

Lactic acid 9.0 公分，KCl 3.7公分，共溶於蒸餾水中，加 4 M $NH_4OH$ 3.0 ml 或 4.5 ml 稀釋至一公升，是爲 pH 2.6或3.0之分散液，若 pH 不等於2.6或3.0可照上法調節之。

## 三、泳動分析

1. 狹條式泳動法

本實驗採用封閉式（固體支持式）狹條泳動法（Closed Strip Method－Solid Support）。濾紙之幅度爲3×50 $Cm^2$，預先飽和以分散液，次於其中點（原點）點附約$\frac{1}{100}$ml 之樣品溶液，外夾以玻璃板兩條，並以夾子夾牢，俾泳動時，濾紙不負荷過量之分散液，露出板外兩端之濾紙，置於兩盛有分散液及置有白金電極之燒杯中，（如圖三）。




第 三 圖

| a. 白金電極 | b. 濾 紙 | c. 分散液 |
|---|---|---|
| d. 夫 子 | e. 玻璃板 | f. 燒 杯 |

泳動時，外加一定電壓之直流電流，經數小時泳動後，乾燥之。以 ammonium purpurate 顯色或以 0.1% oxine－alcohol 與 4M $NH_4OH$ 先後噴霧顯色結果如下：

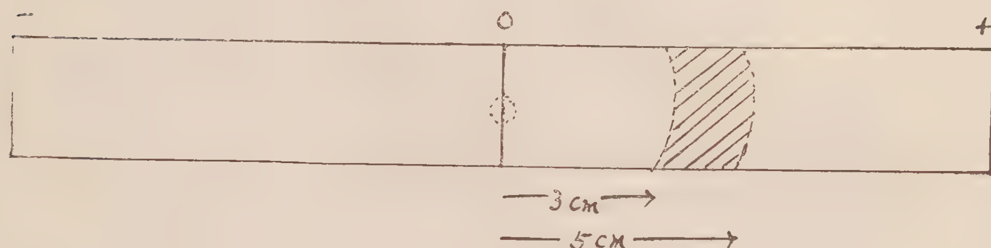
(1) 分散媒　Citric acid－NaCl (pH＝2.8)

固定媒地　東洋濾紙 No. 3

電位梯度　400 V/50 cm

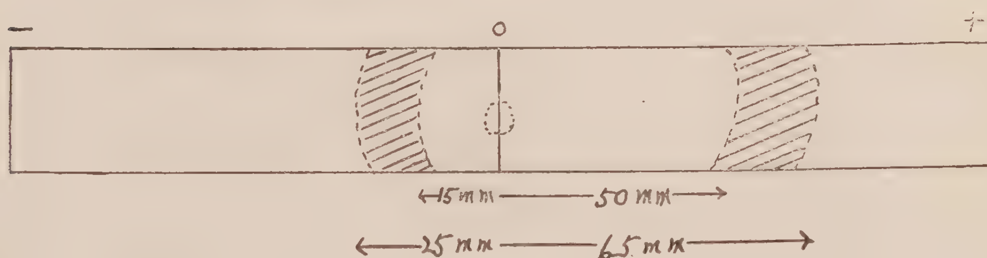
泳動時間　120 min.

平均溫度　　22°C
顯色劑　　Ammonium Purpurate
結　果　　如圖四



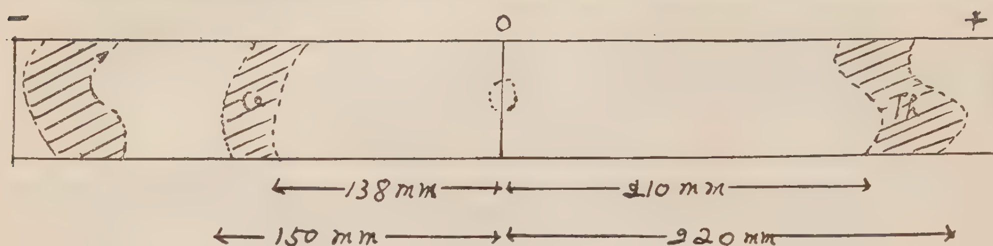

第四圖

(2) 分散媒　　Citric acid - Nacl (pH=2.8)
固定媒地　　東洋濾紙 No. 3
電位梯度　　600 V/50 cm
泳動時間　　120 min.
平均溫度　　25°C
顯色劑　　Ammonium Purpurate
結　果　　如圖五



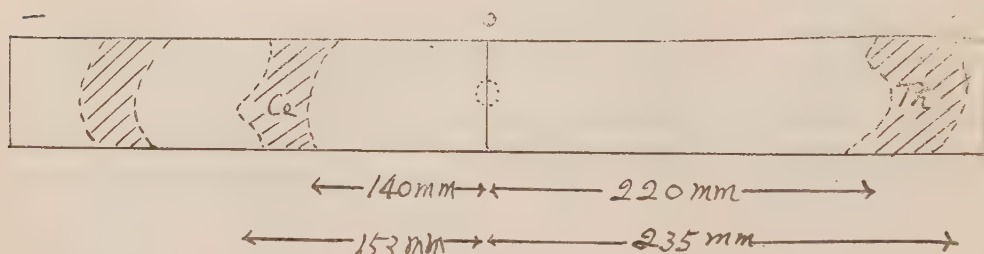

第五圖

(3) 分散媒　　Citric acid - NaCl (pH=2.6)
固定媒地　　東洋濾紙 No. 3
電位梯度　　340 V/50 cm
泳動時間　　270 min
平均溫度　　24°C
顯色劑　　0.1% oxine - alc.
結　果　　如圖六



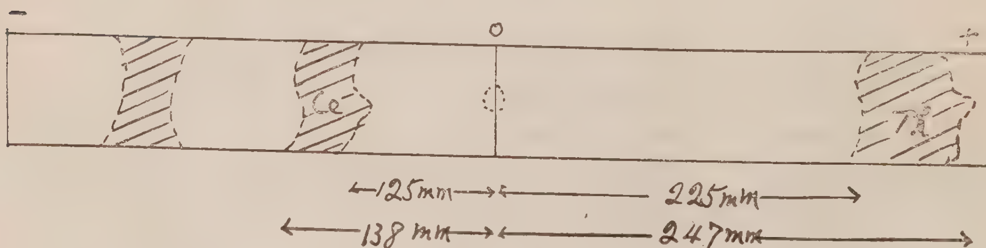

第 六 圖

(4) 分散媒 Citric acid - NaCl (pH=2.6)
固定媒地 東洋濾紙 No. 3
電位梯度 380 V/50 cm
泳動時間 270 min
平均溫度 255°C
顯色劑 0.1% oxine - alc.
結 果 如圖七




第 七 圖

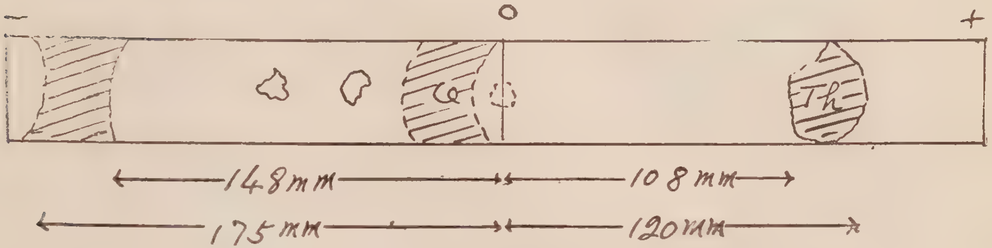
(5) 分散媒 Citric acid - Nacl (pH=2.6)
固定媒地 東洋濾紙 No. 3
電位梯度 460 V/50 cm
泳動時間 270 min
平均溫度 28°C
顯色劑 0.1% oxine - alc.
結 果 如圖八




第 八 圖

(6) 分散媒 Lactic acid - KCl (pH=2.7)
固定媒地 東洋濾紙 No. 3

電位梯度　420 V/50 cm
泳動時間　8 hr.
平均溫度　28°C
顯色劑　0.1%　oxine-alc.
結　果　如圖九

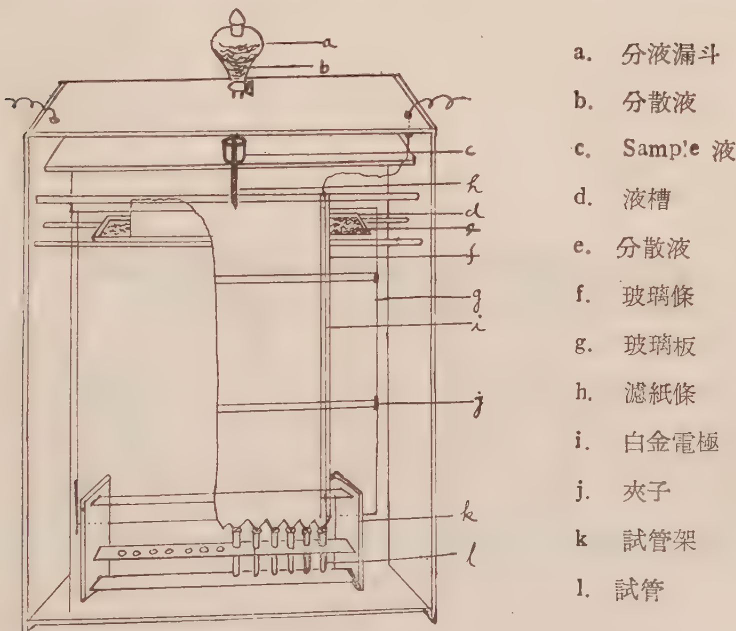



第九圖

由上所得結果與以標準鈰、釷試液泳動結果比較，得知鈰及釷之位置。其他班點爲其他稀土元素，因除鈰釷外，其他稀土金屬之純化合物臺灣買不到，故無從比較檢定之。然若與牧(10)正文所報導之結果比較，最左端之班點可能爲 La 同左第三班點可能爲 Pr, Y, Nd 及其他稀土金屬之混合物。

2.　連續泳動分析

本實驗採取 Strain 式之泳動裝置　如第十圖




第十圖

濾紙幅度爲 50×23 Cm²，下端剪成鋸形，全紙飽和以分散液後，置於泳動裝置中，外通一定電壓之直流電流，泳動24小時，取出乾燥後，以 0.1%　oxine alcohol 及 4M $NH_4OH$ 噴霧顯色，並將流入各試管之溶液檢定釷鈰及其他元素。

(1) 釷鈰混合標準溶液之分離

分散液 Lactic acid-kCl

電位梯度 300 v/23 cm

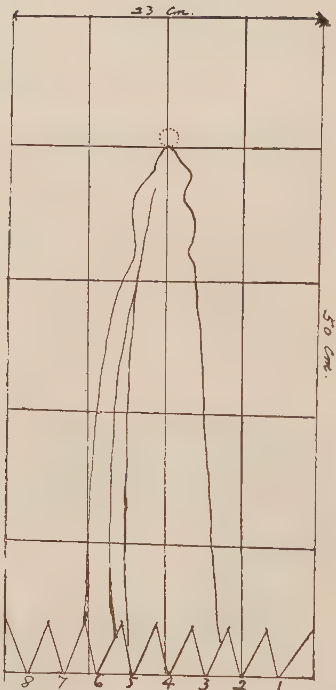
泳動時間 24 hr,

平均溫度 28°C

結果 如圖十一

將流入各試管之溶液以 NaOH 及 $H_2O_2$ 先後處理如表一

由圖十一及表一可知 A 部份爲釷，B 部份爲鈰。




第十一圖
A 部份爲灰白色 B 部份爲淡棕色

表一 釷鈰混合液泳動後流入各試管之溶液處理結果

| 試管號碼 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| 加 NaOH 後所生沉澱 | × | × | 白 | 白 | 白 | 白 | × | × |
| 加 $H_2O_2$ 後之顏色變化 | × | × | 白 | 黃 | 黃 | 黃 | × | × |

(2) 獨居石樣品溶之分離

分 散 液　Lactic acid-KCl

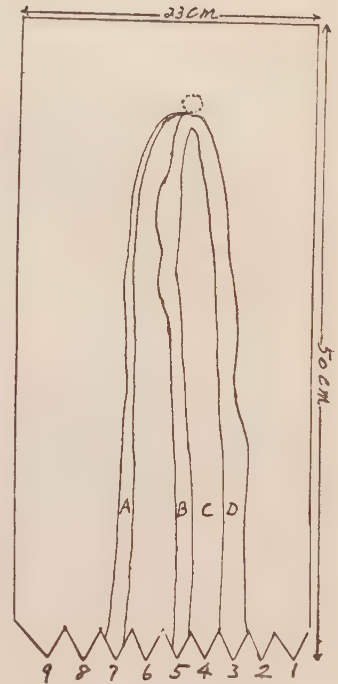
電位梯度　300 V/23 cm

泳動時間　24 hr

平均溫度　28°C

結果　如圖十二

由表二得知圖十二之 A 部份爲 Th, B. C. D 各部則爲未完全分離之 Ce 及其他稀土金屬元素。可見釷已與其他稀土金囑元素完全分離。




第十二圖

A 部份爲灰白色　C 部份爲黃色
B. D. 各爲紫色

表二　獨居石樣品溶液泳動後流入各試管處理結果

| 試管號碼 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|
| 加 NaOH 後所生沉澱 | × | × | 白 | 白 | 白 | 白 | 白 | 白 | × |
| 加 $H_2O_2$ 後之顏色變化 | × | × | 白 | 黃 | 黃 | 白 | 黃 | 白 | × |

(3) 獨居石樣品溶液之分離

分散液 Lactic acid-KCl

電位梯度 420 V/25 cm

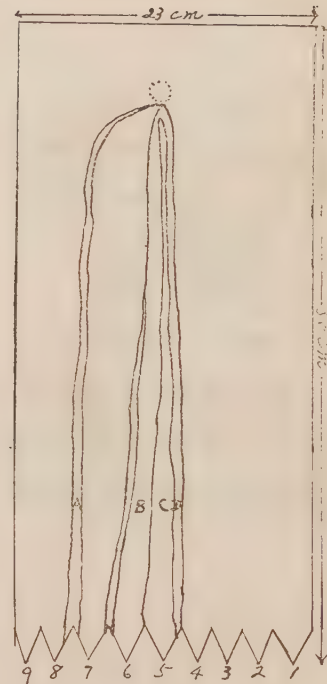
泳動時間 18 hr

平均溫度 28.5°C

結果 如圖十三

將流入各試管之溶液，加 0.1 M. $K_2CO_3$ 溶液，觀其有無沉澱後，再加過量之 $K_2CO_3$. 沉澱溶解者爲Th稍溶者爲 La. 不溶者爲其他稀土金屬。如表三

由圖十三及表三得知 A 部份爲釷，B、C、D 各部份則爲未完全分離之其他稀土金屬元素。




第十三圖

A 部份爲灰白色 C 部份爲黃色
B. D. 各爲紫色

表三 獨居石樣品溶液泳動後流入各試管處理結果

| 試管號碼 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|
| 加 $K_2CO_3$ | × | 白 | 白 | 白 | 白 | 白 | 白 | × | × |
| 加過量之 $K_2CO_3$ | × | 溶 | 白 | 白 | 白 | 白 | 微溶 | × | × |

(4) 獨居石樣品溶液之分離

分 散 液　Lactic acid-KCl

電位梯度　480 V/25 cm

泳動時間　24 hr.

平均溫度　28.5°C

結果　　　如圖十四

將流入各試管之溶液加 0.1 M $K_2CO_3$ 觀其有無沉澱後，再加過量之 $K_2CO_3$・沉澱溶解者爲 Th 微溶者爲 La 不溶者爲 Ce 及其他元素(5)如表四。從而得知，圖十四 A 部份可能爲 Th, C 部份可能爲 La, B 部份爲 Ce 及其他元素，因設備所限，未能作進一步之檢定。




第 十 四 圖

A, C 部份各爲灰白色　B 部份爲黃色

表四　獨居石樣品液溶泳動後流入各試管處理結果

| 試 管 號 碼 | 1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 加 $K_2CO_3$ | × | 白 | × | × | 白 | 白 | 白 | × | 白 | × |
| 加過量之 $K_2CO_3$ | × | 溶 | × | × | 白 | 白 | 白 | × | 微溶 | × |

**結論：** 由上面所得結果可知，以電氣泳動法分離獨君石中各種稀土金屬尚爲可能，於狹條泳動法中已將鉒及鈰分出，且選取 Lactic acid-KCl 爲分散液，較以 Citric acid-NaCl 爲分散液所得結果較佳。唯於連續泳動法中，對於分散液，樣品溶液之流速與電位梯度之配合（因電位高低影响電流强度大小，電流之大小可影响分散液揮發之速率）若能進一步尋出最優良條件，則此實驗當可獲得更圓滿之結果。

# The Separation of Rare Earth Elements from Monazite by Paper Electrophoresis

The purpose of this experimental work is to Separate by paper electrophoresis, the rare earth elements present in the monazite sand found in Taiwan. The Sample of monazite sand selected is first digested with cold conc. sulfuric acid, then precipitated with oxalic acid and ignited to form oxides. finully the oxides are treated with sulfuric acid; ammouium hydroxide, nitric acid to form a solution of rare earth nitrates.

The Electrophoresis is carried out by both the closed strip and continuous methods. Citric acid, lactic acid, potassiun chloride, sodium chloride are mixed in different pairs at several concentrations with ammonium hydroxide as separate electrolytic solutions for electrophoretic magration. thorium is completely separated from the other elements by continuous method in 0.1 M lactic acid-KCl soluton at 300 volts in 24 hours.

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# STUDY ON THE HEMICELLULOSE OF FORMOSAN BAMBOO (Sinocalanus Latiforus Munre)

by

Hoang-Hwa Yang

## ACKNOWLEDGMENT

The writer is deeply indebted to professor F. K. Ho for valuable suggestion and cordial instruction and to Mr. C. H. Hschi, Mr. J. C. Su for helpful advice and assistance throughout the experiment.

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Thanks are also due Mr. W. H. Chang for carrying out the paper patition chromatograph.

## CONTENTS

## 1. INTRODUCTION

Bamboo is one of the most common plants in Formosa, China, Japan and India. It is regarded in our island as an important item for various economical ends, making poles for various uses, bucket hoops, cages or baskets and paper-pulp, etc., and also as ornamental plant.

The bamboo sends out shoots which consist of two parts, the culms or stems, and the sheaths. The shoots, the young culms, are so tender that they can be eaten boiled, and are greatly esteemed as delicious vegetables by Chinese and Japanese both. The stalks which are interrupted in their internal Communication by the nodes or joints, are enveloped in a sheath which rises from the lower and of each node. In China, Formosa and in some districts of Japan, paper is usually manufactued from the crude pulp prepared from bamboos a year old. But nowadays papers manufactured from bamboo at Taicbung and Hwalienkang by the magnesium sulfite mothod of Zuchia[1] have no good quality. The color of the paper is more or less yellow after bleaching. The bad bleachability and black spots formation after bleaching of bamboo pulp may due to the hemicellulose, lignin and pectinous substances because the kind of ash present was said have no influency on the quality of paper. And lignin, pentosan, pectin contents of bamboo are exceedingly large compare with ordinary woods such as coniferous.[1,2.] However, recently it was reported that the bamboo pulps were manufactured by Soda Process, have very good quality both in India and[3,4,5.] China[6].

The study of the chemical compositions of the bamboos is, therefore, very important from the point of view of industrial chemistry and also of biochemistry.

However, K. Miyake and T. Tadokoro[7] have studied the chemical constituents of the shoots of "Sasa painculata, Shibata and Makino", grown in Hokkaido and confirmed the occurrence of xylan, araban cellulose, glucose, fructose and sucrose, but could not detect any starch, galactan, and methyl pentosan.

Yasuo Sasaoka[8] has investigated the carbohydrate of young shoot of bamboo Madake (Phyllo staobys quiliol FM) by means of hydraulic press. From the yielded exdressed juice, after treatment with dilute sulphuric acid, he suceeded to isolate 1—(+)— xylose, d-glucose, and glucuronic acid.

While by same treatment Sitezo-ogri[9] has studied the pentosan of culms of Madake and Mosochiku (Phyllostachyl mitis) and identified the presence of large quantities of xylose with little amount of arabinose in these hydrolysates.

However, so far as writer has learned, concerning the hemicellulose of bamboo only has been investigated by Fritz Hoyer.

This literature, of course can not be found in our island. Consequently, the results is quite obscure. (In Journal of Chemocal Adstract Vol. 38, No. 9, 1944 only reported as follows:

Hemicellulose from wood, bamboo, straw, grass etc.. Fritz Hoyre (to Akt. Ges. fuer Halbzellstoff-Industrie, Ger. 714, 937, Nov. 20. 1941,) (c. f. C. A. 35 8297 1941))

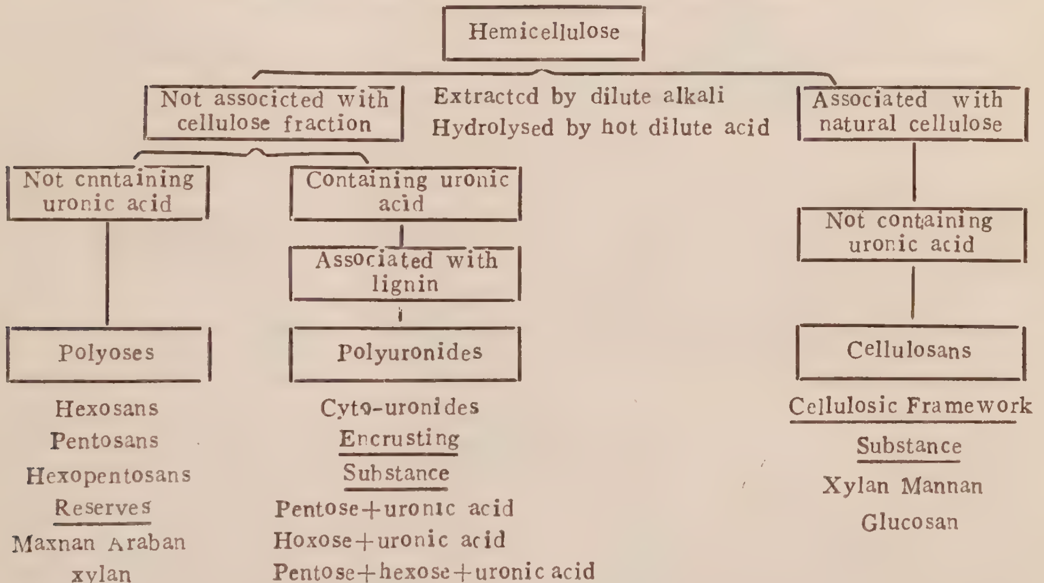
Present study is a small attempt to clarify the chemical composition of the hemicellulose derived from culm of Formosan boomboo Mazu (Sinocalanus Latiferus Munre).

## 1,1. Definition and kinds of Hemicelluloses.

This term was applied by Schulze[10] (1891) to a group of constituents of the cell membrane which unlike cellulose, were soluble in dilute alkali and were readily hydrolized to pentoses and hexoses.

Modern work on the hemicelluloses has shown that in most cases the crude product obtained by alkali extraction can be resolved into several fractions distinguished by their extraction solubilities and hydrolytic products, that many to these fractions contain uronic acids rather than pentosan, constitutes the dominant. Such hemicellulose has been proposed to describe as polyuronides, leaving the older term hemicelluloses for those which yield no uronic acids on hydrolysis.

Table 1. The differentiation of the hemiculluloes.



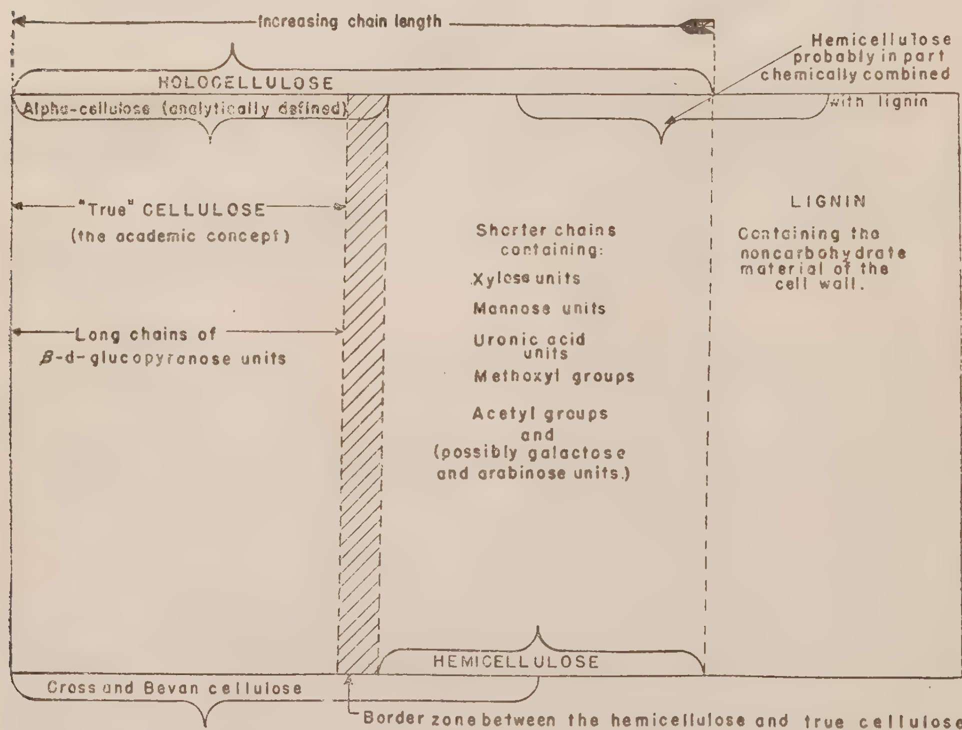

Hemicelluloses from variety of plant materials have now been isolated and examined but few general conclusions can be drawn, the hemicellose of woody tissues is almost always of xylan glucuronide type which has a high ratio of xylose to uronic acid. The hemicellulose fractions from mesquite wood, for example, contain 6 to 12 xylose units to one of glucuronic acid[12], the bark of trees, on the other hand, yields a hemicellulose of another type, a galactangalacturonide, thus the bark of Ash[13] (Fraxinus excelsior) gives 20 per cent of hemicellulose, the hydrolysis products of which are mainly galactose (with little mannose and arabinose) and galacturonic acid.

In addition, however, the extract contains a contribution from the cellulosic fabric itself, consisting of shorter chain polysaccharides which in situ are oriented aud included in the cellulose micelles or reticulate structure, and known as,, cellulosans,, uronic groups are believed to be largely absent from cellulosans.

## 1,2. Properties of hemicelluloses.

Hemicellulose preparations are usually non-reducing, and often more or less soluble or dispersible in water, though not originally extractable by water to any appreciable extent. Some may be precipitated from alkaline solution by simple acidification, others only flocculate out on the addition of alcohol, acetone, or some similar solvents. They are optically active, more frequently laevo-rotatory than dextro-rotatory. Stable methoxyl groups, presumably in other linkage, appear to be a characteristic of many polyuronide hemicelluloses It seems likely that some of the acetyl groups in wood are associated with the hemicelluloses. These, of course, cannot be found in preparations obtained by alkaline extractio but are present in fractions removed by water from holocelluloses.

## 1,3. Schematic concept of the possidle relationship botween the hemicellulose and $\alpha$-cellulose[13]




The above figure is the scheme derived by Rouis, E. Wise which indicates that threshold detween cellulose and hemicellulose. To obviate schematic difficulties, the designation $\alpha$-cellulose., deserves amplification. It is defined in analytical terms. It is the alkali-insoluble fibrous residue obtained under carefuly controlled condition from mixture of polysaccharides, such as those of found in wood "Cross and Bevan cellulose" or "holocellulose". Thus, it is largely" true cellulose" (with its long glucopyranose chains). However, it retains some mannose and or xylose and uronic acid unit as well. This "true cellulose" may be defined acadamically in term of a homopolymer i. e. the alkaliresistant glucose chain in wood.

It is obvious then that α cellulose and cellulose itself are elusive terms that need clear definition. Either method of definition has its weaknesses. The analytical definition of α-cellulose is dependent on a rigid set of arbitrary definition assumes that only glucose units are present in the resistant cellulose chains that there is no possibility that occasionaly mannose, xylose, or glucuronic acid units can occur in such chains. The later assumption is entirely speculative and may be quite unjustified. Ther are no reliable data either for or againist such a hypothesis.

## 1,4. Structure of hemicellulose.

S. J. Mclory[14] have investigated the structure of hemicelluose of Phormium tenax (N. Z. Flax) by means of methylation and proposed following formula for it.

Hemicellulose of P. tenax.

```
Xn 1:4 X 1:4 Xn          where: n=9 or 10
        :
        2                        X=xylopyranose.
        :
        1                        G=D-glucuronic acid.
      X :
        4
        :
        1
      G
```

The calculated equivalent of the hemicellulose (2816-3080) in the formula is in good agreement with equivalent of 3,000 actually found.

## 1,5. Methods of investigation of hemicellulose.

1,5,1. Methods of isolation of hemicellulose.

a. O'Dwyer's procedure[15].

Wood is repeatedly extracted with cold 4 per cent NaOH following treatment with water, 0.5 per cent ammonium oxalate and sold 0.2 per cent HaOH, the two former to remove pectic substances, and the later to remove protein, and expendient later found to be unnecessary sence the nitrogen content of most wood is excedingly low.

b. Norris and Preece's procedure.

Prior to extraction employ a pretreatnetment with boiling alcoholic soda (1 per cent NaOH in 50 per cent ethanol) a device introduced by Norris and Preece[16] with intention of reducing the polysaccharides in alkaline extract. Such treatment later shown[17] to have a serious degradative effect on some hemicellulose[18], preece later recognized this to be so and concurred in its abandonment.

c. Chlorination procedure (Sand and Nutter)[19].

The moist sawdust is treated with excess chiorine gas, and extracted with cold 10 per cent. $NH_4OH$ solution which removes excess chlorine and halogen acids as well as the lignin rendered of the hemicelluloses is extracted with cold 10 per cent NaOH. The

chlorination and extraction are repeated foui times before delignification, and presumably hemicellulose extraction, are complete.

d. Extraction of hemicellulose from holocellulose.

Procedures have now been developed for the complete delignification of cellulosic materials, the residue then containing all or nearly all, the polysaccdarides of the cell wall. The "Skelettsubstanzen" of Schmidt[20] and the "holocellulose" of Ritter and Kurth[21] are representating the cellulose, cellulosans, and polyuronide hemicelluloses, and which provide good starting materials for the study of the hemicelluloses of hard woods. Since their extraction from such residues can be accomplished by mild methods.

i) Schmidt's procedure.

By chlorine dioxide suceeding treatnent to remove lignin he got "Skelettsnbstanzen".

ii) Ritter and Kurth procedure.

Since Sehmit's procedure required approximately one month for completion(17-26 days). it was the desire of Ritter and Kurth to device a rapid method suitable for routine purposes. This aim was achieved by repeated alternate treatments of extractive free wood with chlorine and alcohol-pyridine solution, entire operation requiring only the hours for all but a small fraction of the lignin. The residue later removed by a 30-minute treatment with calcum hypochlorite solution (PH 7.0-7.5). The procedure has a further advantage over that of Schmidt in that the chemicals employed do not offer any serious hazards.

iii) Haegglund and Sandelin's procedure.

In sepeating the work of Ritter and Kurth, substituted acetone for the ethanol used in combination with pyridine for extraction of the chlorinated sample.

iv) Monoethanolamine procedure[22].

Approximately 2 grams of extractive free sawdust (60-80 mesh), whose moisture content is known are chlorinated for three minutes by passing chlorine gas through a funnel inverted over the crusible held in position on a suction flask and kept cool with iced water. The sawdust is then stirred throughly and rechlorinated for two minutes.

The excess chlorine and hyolrochloric acid produced by the treatment are removed by passing alcohol through sample. The chlorine free sample is allowed to stand in contact with hot alcohol-monoethanol-amine mixture for 2 minutes. Then removed with suction. At tbis stage the hard woods become deep red the soft-woods brown.

The solvent treatment is then repeated. After the second solvent treatment, the sample is washed with 95 per cent ethanol, followed by distilled water. The chlorination and extraction treatments repeated until the residue become white following chlorination and is not colored by the addition of hot alcohol-monoethanol-amine.

The author claimed that by this prcedure duplicate holocellulose determinations can be made on extractive free wood sawdust in approximately three hours. As further advantages, it is stated that the chemicals used emit no offensive odors,, and the distinct color end point is obtained, changing from a light pink or light brown to white on removal of the last trace of lignin.

v) Modification of monoethanolamine procedure[25].

Modifying the S. S. Forest Fab. technique Storch and Mueller introduced $C1_2$ into moist beech wood shaving under reducing pressure. The temperature rise was slight, and the improvement in chlorine absorption marked.

Each chlorination is followed by washing with $H_2O$ and treatment with a mildly basic solvent ($Ca(OH)_2$, $NH_4OH$ or $Na_2CO_3$) followed by washing and rechlorination. Subsequently material is again washed, bleached with NaC1O (0.5% active C1) for an hour followed by washing.

Each chlorination required about 30 min. with 20 g wood. The holocellulose content calculated on a lignin free basis was 76–77% when $NH_4OH$ or $Ca(OH)_2$ was used. Holocellulose when treated with 0.2% NaOH lost only about 10% of its original weight, but when such treatment was followed by extn. with 4% NaOH approx. 25% of holceilulose was removed. A loss of 34% of holocelluiose was noted when 17.5% NaOH was used. This indicates an $\alpha$-cellulose content (free from pentosans) of about 43.5%.

vi) Sodium chlorite procedure[24].

The advantages of the shortened chlorite-holocellulose procedure are 1) the ease of manipulation. 2) Its reproducibility. 3) The relatively slight degradation of the polysaccharides. 4) The possibility of obtaining large scale laboratory preparations. 5) The fact that it pemits the quantitative separation and the study of both the hemicellulose and cellulose fractions, and 6) that it expedites the isolation of small amounts of pectic material found in wood.

Ten-gram sample of air dried unextracted wood prepared by passing through a Wieley mill, are heated to 60°C with a solution containing 50 ml. of water, 50 ml. of acetic acid and 50 g. of sodiumchlorite. After the initial heating the delignification is allowed to proceed at about 30° C for 24 hrs., the mixture being stirred at intervals. At the end of this period the nearly white, which retained its wood structure was filtered by suction and washed with ice water. The hemicelluloses are removed in any desirable number of fraction by successive extractions with aqueous potassium hydroxide in an atmosphere of nitrogen. It was found in this study to begin with 4 to 5% and to end with 24% potassium hydroxide. This procedure is afterward modified by wise. Murphy and Addieco, A. A,[25], so that the total chloriting period could be shortened to 3 to 4 hrs.

vii) Procedure for isolation of hemicellulose directly from wood.

Hemicellulose can be prepared within a single working day and the procedure gives higher yields than do the direct mothod previously described.

By treating 525 g. air-dried sugar maple sawdust at 65–75°C. with 884 ml, 20% KOH for 2 hrs. then adding 5900 ml. $H_2O$ and heating the stirred suspension for another 2 hrs. an apreciable fraction of the hemicellulose (I) was extracted. The alk. soln. of Hemicellulose was filtered and I was pptd. with an excess of MeOH and bleached with $NaC1O_2$ and AcOH. Hemicellulose obtained in 14.6% yield contained no lignin, 7.1% ash, 2.0% MeO, 76.6% pentosans and 16.67% uronic anhydride. The remaining wood residue, when treated

with AcOH and $NaClO_2$ and then extd. with hot aq. KOH by the above method, yield 3.5% 2nd hemicellulose fraction which remained 5.2% lignin, 3.03% MeO. 77.7% pentosans and 9.8% uronicanhydride.

1,5,2. Methods of identification of hemicelluiose.

Identification of component sugars and sugar acids is effected after hydrolysis, usually by boiling with dilute acid or sometimes by pressure treatment. Qualitative methods that have been used in the identification of the sugars ordinarily occuring in hemicelluloses involve mainly the preparation of osazones or some other characteristic derivatives. The benzimidazole com'pds and paper partition chromatography, sbould prove particularly valuable for this purpose. procedures applicable in the characterization of the uronic acid has been summarized by Norman.

a. Methods of identification of xylose.

i) prepaıation of the osazone.

ii) preparation of xylonic acid-cadmium bromide double salt.

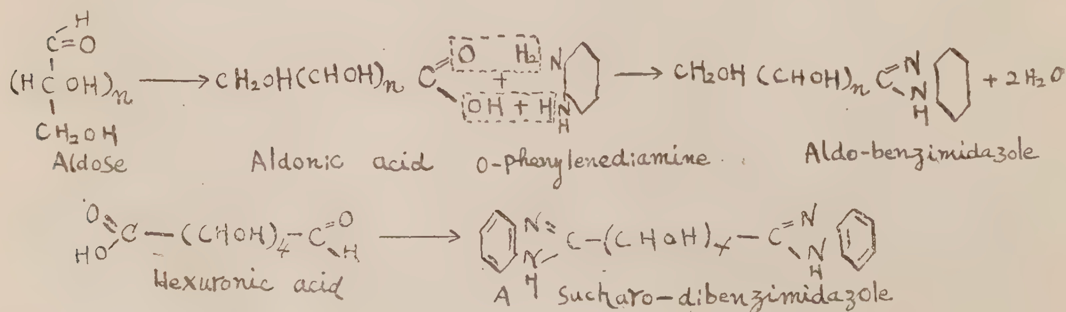
iii) detection of small amonnts of arabinose in xylose preparations.

After removing the bulk of the xylose by crystallization the syrup (0.5 g.) in 75% alcohol (6 ml.) is treated with $\alpha$-benzy. phenylhydrazine (0.5 g.). After 12 hrs. arabinose benzyl-phenyl hydrazone is precipitated and is crystalliged from alcohol. M. P. 172.°

iv) A simple microbiological method has been developed which permits the determination of 12 to 50 mg. of xylose in the presence of glucose, mannose, arabinose, and glucuronic acid, with an accuracy of 96 to 104%. It depends on the use of Hansenula suaveolens (N. R. R. L. No. 838) which ferments xylose quantitatively but not arabinose, rhamnose, and glucuronic acid. Inasmuch as N. R. R. L. No. 838 also ferments glucose, the hexoses must be fermented prior to its use. Such fermentation is effected by Saccharomyces carlsbergensis (N. R. R. L. No. 379), which has only a very slight action on xylose, an error for which due correction may be made[27].

b. Identification by preparation of benzimidazole compounds.

The procedure[28,29,30]. is based on the combination of 1) a potassium hypoiodate methanol oxidation and 2) the use of O-phenylendiamine as reactant for the characterization of the resulting aldonic acids as benzimidazole delivatives according to the following equation.



c. Paper partition chromatography[31].

Louis, E. Wise recently reported, paper partion chomatography was applied to the separation of simple sugars obtained by partial hydrolysis of holocellulose, cellulose, and various pulps.

Arabinose in small amount was found in the hydrolyzates of sugar pine, western white pine, and Vilginia pine, obtained by heating 0.01 $H_2SO_4$. Its presence was shown chromatographically and by formation of diphenyl hydrszone. M. P. 197–200°

## 1,6. The substences resistant to hydrolysis of the hemiceiluloses (body X. aldobionic acid, and oxy cellulose).

The hemicelluloses of mesquite wood have been extensively studied by Sand and Gary[12] according modifed procedure of O'Dwer's method. All components were accounted for armost completely in terms of xylose, hexuronic acid, and ether-linked methoxy groups, together with small but variable amounts of an insoluble residus remaining after hydrolysis. This residue, which they described as "body X" was almost certainly lignin.

The development of method for the preparation and examination of the hemicelluloses from wood may well be followed through the sequence of papers by O'Dwyer[15] extending over the past twenty years. In her earlier work, the hemicellulose of American white oak was investigated. The extraction was followed just writer has mentioned in the methods of extraction of hemicellulose. She divibed the hemicellulose in two fractions. Fraction A (hemicellulose A) was obtained by precipitation with acetic acid, and Fraction B (hemicellulose B) by subsequent addition of 2 volumes of alcohol. On hydrolysis with 1% sulfuric acid for 3 hrs, xylose was liberated and after neutralization with barium carbonate, the barium salt of an acid was precipitated by alcohol. The analysis of this salt agreed the barium salt of an aldobionic acid composed of xylose and methoxy hexouronic acid.

Campell[32] has reported that he isolated from the sap wood of oak and walnut starch that contained acidic groups and was composed of approximately 90% anhydroglucose unit linked to an aldobionic anhydride (probably glucose-glucuronie acid) which may be partly methylated.

However, sand and Nutter[19] have investinated the hemicellulose of mesquite wood by the chrolination procedure and found the substance resistant to hydrolysis was oxy-cellulose.

## 1,7. Industrial Importance of Hemicelluloses.

### 1,7,1. In the pulp and paper industry.

There is an increasing realization that this group may be more valuable than hitherto supposed. The process of isolation of cellulose from wood, usually centers round the removal of lignin. Virtually all industrial delignification processes, however, effect at the same time the removal of hemicelluloses to different degrees, according to the conditions of the treatment and the nature of wood. It may sometimes be the case that delignification is less complete than the removal of these acompanying polysaccharides. Because the chemistry of the hemicelluloses is still obscure and the determination difficut,

very few technical studies of their fate in pulping processes have been made. (but hemicellulose in sulfite waste liquor had been investigated by Japanese wood chemist, Uchida[33]).

In practice, an appreciable fraction of the wood may remain unaccounted for, or unnecessarily discarded. There are many purposes for which a higher $\alpha$-cellulose is not essential. It is forshadowed by a number of interesting papers[34,35,36,37,38,39.] on the properties and utillization of holocelluloses prepared from wood, preliminary studies on the paper making qualities of holocellulose preparations have given encouraging result. sheet of good mechanical properties have been obtained despite the relatively high content of non-cellulosic material. Holocellulose obtained from spruce was processed in a labortory beater, its physical characteristice studied at intervals.

The less resistant carbohydrates, which include both polyuronide hemicelluloses and cellulosanes, have an important influence on the development of a gelatinous hydrate. The product has good fiber bonding and developed exceptional strength characteristics. On the basis of these results, Hontz and Kurth40 suggested that the cooking process in production of pulps to be used for highly hydrated papers should be conducted, in such a manner that as much as possible of the hemicellulosic materials is retained.

1,7,2. Hemicellulose nitrate[41].

Attempt has been made to prepare the nitrate of hemicellulose. The nitrates obtained by treating hemicellulose with AcOH and $HNO_3$ and also with $H_2SO_4$ and $HNO_3$ containing small amount of $H_2SO_4$ arc stable, and no sign of decomposion was seem in 8 months.

1,7,3. Films from hemicellulose acetates.

Chales L. Smart and Royl. Whisher[42] from hemicellulose A (I) (A higher mol. polysaccharide prepared by neutralizigg alk. concob hemicellulose upon acetylation with $Ac_2O$ in the presence of 0.25% $HNO_3$ produces a white fibrous acetate containing 36.6% Ac groups, when cast from dioxane, $C_5H_5N$, or $CHCl_3$-MeOH (9.11), clear films are produced showing a tensile strength of 7.2 Kg/s. g. mm.

## 1.8. unsettled problems.

(1) The structure of hemicellulose must be established in more sure basis.

(2) Is the conbination between hemicellulose and lignin entirely physical or chemical? If it is chemical combination in what linkage they are combined?

(3) In what manner hemicellulose combined with cellulose? What is the clear distinction between cellulosan and hemicollulese?

(4) In hemicellulose molecule, acetyl and methoxyl groups are in what linkages combine with other groups?

(5) The structure of lignin must be established in more sure basis. In 19 7, O. Mueller[43] in Gaettingen University investigating the hemicellulose of beech wood and advanced the hypotnesis that lignin fragment remaining in holocellnlose is polysaccharide in nature and may be an aldose condensation product and that the assumption that carbo-

hydrates of cell can be determined quantitatively by difference after making a single lignin determination is erroneous. What may be the fate of this hypothesis?

(6) Is protopectinase and hemicellulase identical or not[44]?

(7) What is clear relation ship between hemicelluloses and cellulosans?

(8) Is the structure of hemicellulose one of relatively simple chain molecules or is one of large chain molecules varying numbers of recurrent?

(9) Hemicelluloses are presumably derived from starch presumably by oxidation and decarboxylation, or from pectin, but is it really to be so[32]?

## 2. EXPERIMENTAL

### 2,1. Cutting down of the Bamboo.

The specimens were grown in Zusan near Taichung, and were secured through the courtesy of Mr. S, Lin.

One year old (total length 20.7 m., largest diameter 14.5 cm.) and few years old (total length 16.5 m., largest diameter, 12.0 cm.) of culms of bamboos were cutted down on August 24 th. 1950. from bamboo jungle. (In each hectre of jungle there are average 1200 stumps of bamboo). The nodes and sheaths were removed. Each other nodes were collected and weighed. The sample has total weight of 56.4 Kg. and contain about 85% of water. The sample transported to the laboratory and started the experiment after 3 days.

### 2,2. Preparation and analysis of the sample.

Sample was cutted longitudinally in small pieces, chipped by scissors in proper sizes, and passed through a Wiley mill. From 56.4 Kg. of clums, about 10 Kg. of Wood powders were obtained.

That passed 20-48 mesh (mesh to inch) were used for general analysis of the bamboo and the powder has 48-100 mesh sizes were used for the extraction of the hemicelluloses.

The results of general analysis of the bamboo are indicated at TAELE 2. Analytical Results of Sinocalauus Ltiforus Munre.

| | mois-ture | crude protein | crude fat | crude fiber | crude ashes | pento-san | s.n.n.c. |
|---|---|---|---|---|---|---|---|
| air dried basis | 15.69% | 1.50% | 1.70% | 42.26% | 2.63% | 16.27% | 20.01% |
| water-free basis | | 1.88% | 2.3% | 50.11% | 3.12% | 19.32% | 23.44% |

s.n.n.c. = soluble non-niterogenous com'pd

From above results it may be safely to say that almost all of soluble-non-nitrogeneous compounds may regard as lignin and the contents of pentosans of the bamboo are relatively small compare with other spacies or varieties of the bamboos[1,2.]; i. e. Phylostachys. reticulatac. Koh., Bambasa. slenostacya. Hack., phyllostachys. eawtis.

The sample was further subjected to brief general analysis of wood. The results are indicated at Table 3.

| moisture | crude ashes | other extract | Cross Beyan cellulose | pentosan | Total nitrogen | lignin |
|---|---|---|---|---|---|---|
| 15.69% | 3.12% | 2.13% | 54.95% | 19.32% | 0.30% | 24.44% |

The contents of lignins and pentosans were determined according to the method of standard wood analysis of Japan[45], and the procedure of U. S. Forest[46] Products Laboratory, respectively. The estimation of Cross and Bevan's cellulose was carried out after the procedure described in the mannual[47].

## 2,3. Preparation of the hemicellulose.

Under the circumstance, because no sodium chlorite were available, choiced the Procedure of Norris and preece.

2,3,1. The removal of pectins.

a. hot water treatment.

In a flask containg 500 g. of the sample added 3.5 L. of water and heated on a water bath at 80-90° C for 15 hrs. The mixture was allowed to cool, filtered through muslin. To the transparent filtrate being acidified with glacial acetic acid, was poured with equal volume of 96% ethanol, a white precipitate was recovered. The residue was further subjected to the same treatment for 1 hrs., but could not obtain any precipitate. Yield of crude pectin obtained from 6.5 Kg. sample was 30.2 g..

This crude pectin has been studied so that not analalized.

b. 0.5% ammonium oxalate treatment.

The removal of pectin from the residue is completed by repeating extraction with 0.5% ammonium oxalate solution. To the residues after above treatment add 3.5 L. of 0.5% ammonium oxalate solution and were stood for 7 hrs on a water bath at 80-90° C.. To the filtrate of the above mixture poured into 10% cupper sulfate, observed blue precipitates are forming, but not recovered.

2,3,2. The removal of lignin.

The removal of lignin of the above residues was carried out two extractions with 3.4 L. of NaoH, each extraction being carried out under reflux for 4 hrs.. After second extraction, the filtered tissue was further filtered through muslin, excess liquid was again removed at the press.

2,3,4. The isolation of the hemicelluloses.

a. The extraction with 4% NaOH solution.

From 1000 g. of the above resiuethe first extraction of the hemicelluloses was carried out with 6 L. of 4% NaOH solution. The mixtures were allowed to stand for 48 hrs. at room-temperature with occasionally stirring. The filtered extract left standing in the refriginerator over one night at 5°C. was gradually added with constant stirring rather more glacial acetic acid than is necessary to neutralize it. Observed the hemicellulose corresponding to the A fraction in O'Dwayer's procedure was precipitating but not separat by the centrifuge. Equal volume of 90% alcohol is then gradually added with constant stirring,

namely, corresponding to A and B fractions of O'Dwyer's procedure are precipitated together. The precipitat is then treated with gradually increasing strengths of alcohol, in the usual way for obtaining a dry product. Drying is completed in vacuo, because no phosphorus pentoxide was availabie, drying was carried out over calcium chloride.

b. The extraction with 10% NaOH solution.

The above residue was further extracted with 10% NaOH solution, namely, to 2000 g. of the residue was added 7 L. of 70% NaOH solution, and the mixture was allowed to stand for 48 hrs. at room-temperature. At this stage because the viscosity of the solution was very high, so that the stirring was very difficult. The extracted solution was filtered through muslin, the filtered extract let stand over one night in refrigenerator and treat as before (as in case of the hemicellulose A), the yields of crude hemicellulose obtained from 6.5 Kg. of the sample calculated on dry weight 230 g..

The study of the above residue and purification of the hemicelluloses were not carried out, because under the circumistance it was quite difficult to accomplish.

## 2,4. General properties of the hemicelluloses.

The product obtained by this method consists a fine greyish white amorphous mass, and more or less soiuble or dispersible in cold water. It is soluble in boiling water, forming a gelatinous mass on cooling. It is easily soluble in cold 4% HaOH solution. It does reduce Fehling solution and is laevo-rotatory, it form gelatinout insoluble copper componnd on addition of excess Fehling solution, and the filtrate obtained is quite transparent. The results of the estimations of ash content, specific rotation, pentosans, body x. are indicated at Table 3.

Table 4. general properties of the hemicelluloses.

| | Hemicellulose A | Hemicellulose B |
|---|---|---|
| ash | 5.07% | 3.98% |
| $[\alpha]_D^{25}$ | 78.2° | 89.2° |
| xylan | 75.67% | 86.97% |
| Body X | 6.17% | 8.87% |

The hemicellulosos when distillate with HCl (sp. gr. 1.06) yield furfural and it may be regarded as derived from xylan as indicate in later, so that It calculated as xylan. Because some color tubstances, perphaps lignin, are still remain in the hemicellulose preparation, the observation of rotation of the hemicelluloses were very difficult.

## 2,5. The estimations of reducing powders of the hemicelluloses.

In order to ascertain the relation between the concentration of dil. acid and the amount of reducing sugars present, each 0.5 g. of the products were subjected to hydrolysis with 500 cc. of 0.1, 0.2, 0.3, 0.4, 0.5, 1% sulfuric acid in autoclave, within 20 min. temperature of outoclave was rised from 100°C to 150° C and maintained this temperature (about 4 atmospheres) for 30 min..

After neutralization and removal of humin substances (Body X) diluted to 200 cc and took 20 cc for ascertaining the reducing power of the hydrolysed soluions in each by Betrand's method.

It were found that:

In case of hemicellulose A,

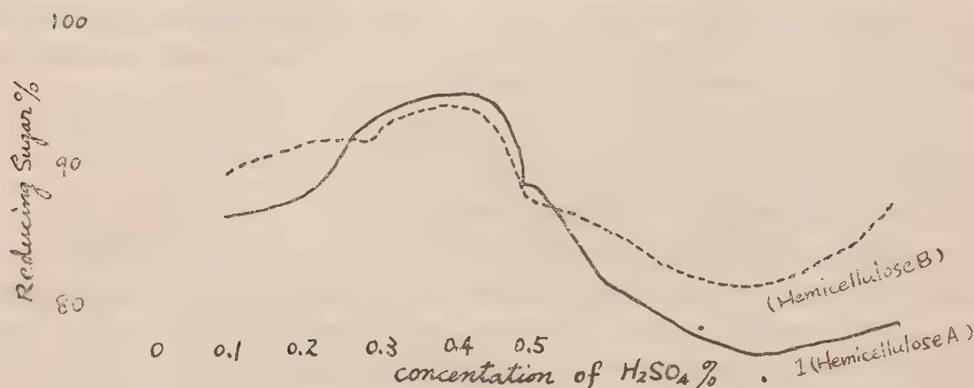
| $H_2SO_4$% | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 1 |
|---|---|---|---|---|---|---|
| reducing power% | 86.4 | 88.3 | 92.5 | 94.4 | 88.2 | 78.0 |

In case of hemicellulosé B,

| $H_2SO_4$% | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 1 |
|---|---|---|---|---|---|---|
| reducing power% | 89.2 | 91.0 | 91.6 | 94.1 | 87.3 | 87.8 |

of reducing sugar reckoned as xylose were obtained.

Figure 1. the relation of the concentration dil. $H_2SO_4$ and reducing sugar present.




## 2,6. The examination of the hydrolysis products.

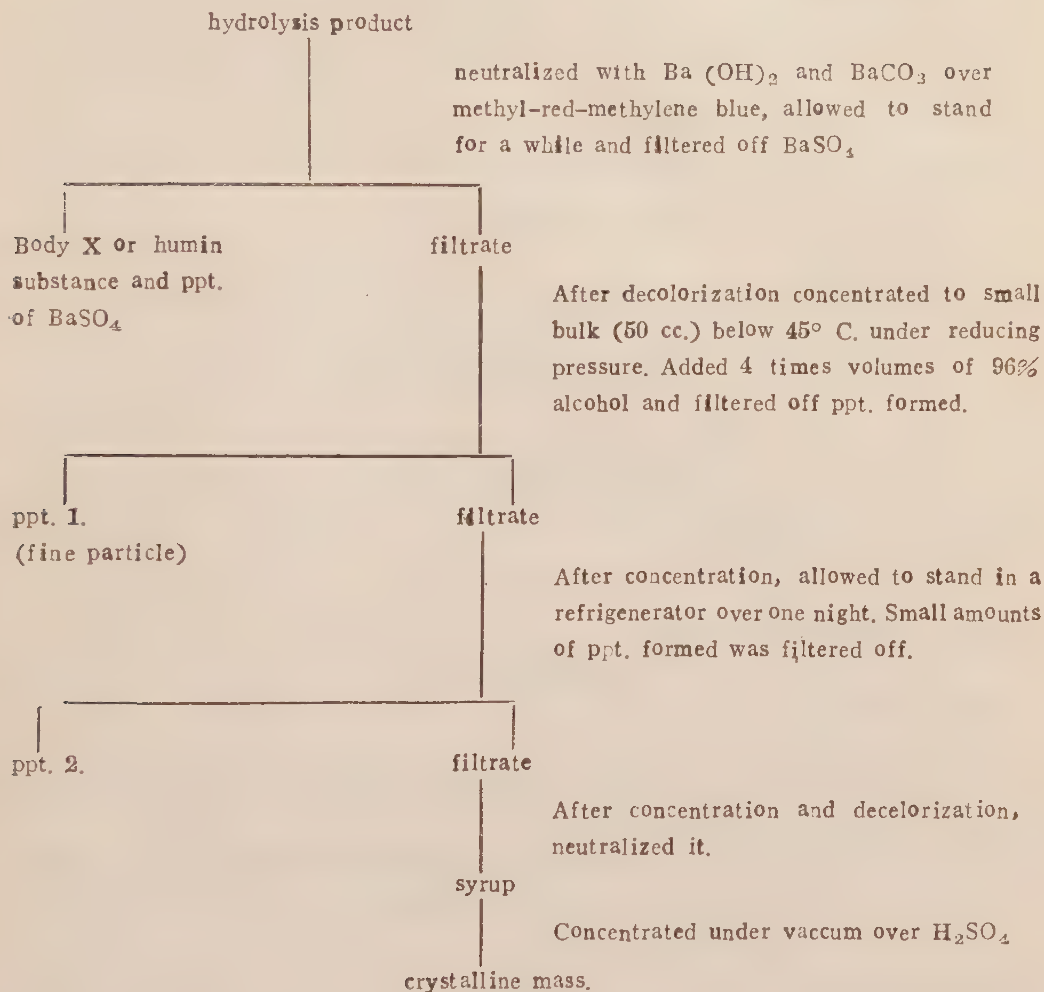
Rest on the basis of above results to 35 g. of the hemicellulose A in autoclave were hydroyzed with 2000 cc. of 0.4% $H_2SO_4$ solution. Within 20 min. the temperature of autoclave was rised for 100° to 150° C. and maintained this temperature (about 4 atmospheres) for 30 min.. The hydrolysed solution at the end of this time still contained a small proportion of insoluble matter and has light yellow color. After sufficient quantity of barium hydroxide was added exactly to neutralize the solution. The solution was further neutralized with barium carbonate over methyl-red-methylene blue ( PH 5.4 ) and filtered.

The solution being decolorized with charcoal, was concentrated under reduced pressure below 45° C. to small bulk (50 cc.) and further subjected to the decolorization. 4 times volumes of 95% alcohol was added to it to get rid of any barium sulfate remaining, and after the decolorization and filtering, at end of this stage the solution was already in sirupy condition. The sirup has a light yellow color.

Toe hemicellulose B 27.4 g. were subjected to same treatment just as before stated, the syrup also has a light yellow color.

A little more alcohol was then added and the syrups were allowed to evaporate slowly over sulfuric acid in the desicator. Then, the desicator let it stand in a refrigenerator at 5° C. for 48 hrs. with occasionally stirring of the syrups, a white crystalline mass slowly formed.

The procedure is illustrated at Chart 1.




——Chart. 1.——

2,6,1. ppt. 1.

It consists of fine white particles. When it was subjected to naphthoresorcinol test the result was negative. ppt. 1 when heated in a crusible no chared phenomena was observed.

2,6,2. ppt. 2.

When ppt. 2. was subjected to char, the white color not turns to black. On further heating ppt. 2 not disappear and still has a white color. ppt. 2 consist of some inorganic saits is apparent.

2,6,3. The examination of reducing sugars.

The syrups deirved from the hemicellulose A and B have the sweetish tastes and have light yellow colors.

The syrups were subjected to general qualitative tests of monosaccharide, the results

are indicated as follow.

a. qualitative tests of pentoses.

1) color test of pentose.

i) Wheeler and Tollen's test.
Hemicellulose A (++), Hemicellulose B (++).

ii) Schiff's test.
Hemicellulose A (++), Hemicellulose B (++).

iii) Bual's test.
Hemicellulose A (++), Hemicellulose B (++).

iv) Rosenthaler's test.
Hemicellulose A (++), Hemicellulose B (++).

v) Van der Haar's test.
Hemicellulose A (++), Hemicellulose B (++).

2) color tests of methyl pentose.

i) Widtsoo and Tollen's test.
Hemicellúlose A (—)?, Hemicellulose B (—)?.

ii) Oshima and Tollen's test.
Hemicellulose A (—), Hemicellulose B (—).

iii) Maquenn's test.
Hemicellulose A (—), Hemicellulose B (—).

All the color tests of pentose were predominately positive for its presences, while in cases of methyl pentose were negative.

It will be safely to say that because of the simultaneous presence of large amounts of pentose, those of methyl pentose were greateiy inhibited.

b. qualitative tests of hexoses.

1) fermentation test.

The syrups were diluted and subjected to Lindner's micto methode[48] by means of the fermentative power of "Press-hefe Rasse 12".

Both syrups derived from hemicellulose A anb B were stronly fermented. Consequently, the presences of zymohexoses in the syrup are apparent.

2) the color tests of ketose.

The diluted syrups further were subjeced to the color tests of ketose. The results is as follow.

i) Pinoff's test.
Hemicellulose A (—), Hemicellulose B (—).

ii) Seliwanoff's test.
Hemicellulose A (—), Hemicellulose B (—).

iii) Ihla-Pechmann,s test.
Hemicellulose A (—), Hemicellulose B (—).

The results indicated no ketose is present in the syrups.

3) the oxidation of the syrups by $HNO_3$.

D-galactose, l-galactose, and d-galacturonic acid, when are oxidized, produce music acid. The syrups were subjected to music acid test, but the results were negative.

c. qualitative test of utonic acid.

The syrups were further subjected to naphthoresorcinol test, but the results were negative.

2,6,4. the isolapions of d-xylose.

As illustrating in Chart 1. the syrups derived from hemicellulose A and B in desicator with occationally stirring, the white crystalline masses were slowly formed.

Yields of crystalline masses from hemicellulose A 35 g. and hemicellulose B 27.4 g. were 18.2 g. and 15.2 g. respectively.

The crystalline mass dissolved if 95% alcohol and allowed to stand in a refrigcnerator with occasionally stirring, gradually prismic crystalls formed.

They melted at 142-145° and $[\alpha]_D^{25} = +30.4°$(after 20 min.), +28.2° (after 37 min.), +25.2°(arter 40 min.), +24.3°(after 50 min.), +22.6° (after 60 min.), +19.6° (70 min.), +19.6°(80 min.),

According to Brown[49] xylose has $[\alpha]_D^{20} = +85.9$ (after 5 min.), and this value gradually decrease with time. After 2 hrs. it showsa constant value +18.6.°

However, Schulze and Tollen[50] indicated for xylose $[\alpha]_D^{25} = +19.248$ (p=10.0829).

As a means of further identification, Bertrand's reaction[51] was carried out. Each 1 g. of the white crystalline masses derived from the hemicellulose A and B, were mixed with 2.5 g. of cadmium carbonate and gradually with cooling mixed with 2 g. of bromine. The mixtures were sllowed to stand for 20 hrs., then brought to boiling point and the residue washed with boiling water. The filtrates were mixed with alcohol and the salts came out in characteristic boot-shaped crystals. ( $(C_5H_9O_6)_2Cd-CdBr_2-2H_2O$).

By the properties of melting poit, specific rotation and formation of the double cadmium salt of xylose as indicated above, the crystals were identified as xylose.

2,6,5. the examination of other sugars.

a. the preparation of the osazones.

Each of 1.5 g. of the sylupy crystalline masses derived from hemicellulose A and B, were mixed with 3.5 g. of phenyl hydrazine, 3 cc. of glacial acetic acid, and 25 cc. of watér. After half an hr., no precipitation takes place, so that no trace of mannose is present. The mixtures were then heated on the water bath for 1-1/2 hrs.. A little turbid phenomena was observed, so that trace of glucose may present. As mentioned above, by fermentation test had alreday identified the presence of zymohexose in the syrup, while the ketose and music acid test were all negative. and now indicate no trace of mannose is present in the syrups. Consequently, glucose must a component of both hemicellulose A and B. This fact was further confirmed as below by paper chromatography.

On cooling large amount of xylose osazone came out in yellow crystals.

b. the preparation of arabinose-diphenyl-hydrazone.

After removing the bulk of xylose by the crystallization on the syrups in 75% alcohol were treated with diphenyl hydrazin which have been dissolved in ethanol, and let allowed to stand in the refrigenerater for 24 hrs., the white crystals were appeared. Under microscope, they have needle shapes.

c. the analysis by paper patition chromatograph.

The syrup derived from hemicellulose A and B after removing the bulk of xylose, subjected to one dimensionol paper patition chromatograph (ascending methode).

The relults are indicated as follow.

| substance idenified | BuOH-AcOH-H20 (4:1:1) | | phenol satd. with H20 | |
|---|---|---|---|---|
| | Rf | color | Rf | color |
| glucose | 0.15 | a. bright brown<br>b. dark brown<br>c. brownish yellow | 0.37 | a. bright brown<br>b. dark brown<br>c. brownish yellow |
| xylose | 0.23 (over-lapped) | a. red<br>b. chocolate brown<br>c. pink red | 0.44 | a. red<br>b. chocolate brown<br>c. pink red |
| arabinose | | | | a. red<br>b. chocolate brown<br>c. pink red |

a. color developed with anilin hydrogen phthalate.
b. color developed with benzidine.
c. color developed with $\alpha$-naphthyl amine.

By the above results, the presences of small amounts of arabinose and glucose in the syrups derived from hemicellulose A and B were confirmed.

## 2,7. Disussion of the experimental results.

K.Ono[52] has investigated the components of the hemicellulose of bagasse and found the chief product of hydrolysis was xylose. He reported the hmicclluloses were very rese-mble to Esparto-Xylan (according to Haworth[53], Esparto-Xylan has a structure, arabofur-anose-$(\text{xylose})_{16-17}$ xylose).

While H. kurasawa[54] has studied the same subject and concluded the small amounts of arabinose were present in the hemicellulose. Except xylose and arabinose, he also insisted that small amounts of dextran (glucosan) may be simultanously present.

However, the hemicellulose A and B of the Formosan bamboo, contain 75%. and 85%. of pentosans, respectively and those chief components are apparently xylose. Except xylans, writer has confirmed the simultaneous presence of small amount of arabinose., and dextran (glucosan) in the hemicelluloses.

The above results is very interesting and found out that the hemicelluloses of the

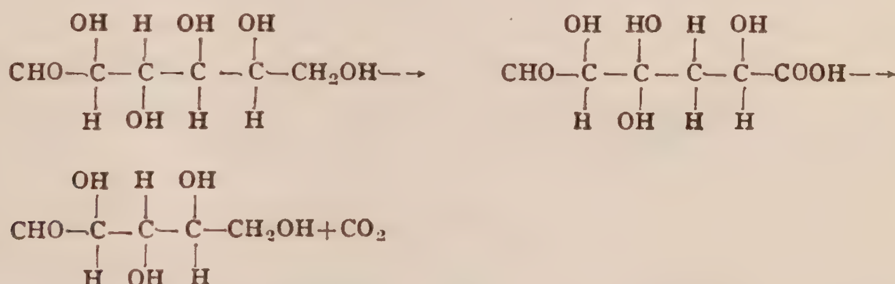
bamboo are very resemble that of the bagasse.

Furthermore, this results coincided with the results of the study of pentosan of the culms of Madake by S. Ogri[9], except the fact that in the components of the hemicellulose of the culms of the bamboo, there is a glucose unit.

As mentioned above, although the hemicelluloses contain A and B fraction correspon-ding the hemicellulose A and B of O'Dwyer's prosedure, but not separated. Consequently, it is quite difficult to conclude now that whether the glucosans in the hemicellulose were derived from cellulosan origin or not.

The hydrolysis of the hemicelluloses were carried out under pressure treatment, so that whether the uronic acid in the hemicelluloses were decomposed during the processes or not is quite in question, but still it is interesting that the uronic acid is not present in the hemicelluloses of the culms of the Formosan bamboo.

As for the chemical reaction which occurs in the hexose in the plant thissues it was assumed that first the $CH_2OH$ group of the molecule was attacked to convert the carboxyl group by partial oxidation in forming glycuronic acid which was secondarily transformed into 1 (+) xylose by the splitting-off of $CO_2$ from the molecule.



Thus, 1 (+) xylose in the plant resulted from d-glucose, and glycuronic acid stands as an intermediate state in this transformation.

The fact which has been mentioned by many chemists that d-giucose and galactose have almost always been found in nature with 1 (+) xylose and 1 (+) arabinose should account for the formation of the pentoses by the metabolic changes of the hxoses in plants.

Moreover, it is a notoworthy fact that glycuronic acid[55] which was described as an intermediate product of glucose metabolism in nature, was isolated from the expressed juice of the shoots[8]. Confirmation of this substance was made by determining the rotary power of its lactone, m. p. 166-9° $[\alpha]^{\circ}=18.64$-1.6° and also by transformation into the barium salt of phynyl hydrazone, m. p. 192° and hydrazone, m. p. 181°

Consequently, the results also confifmed the view that although the relatively large amounts of hexoses, glucuronic acid, are present in the shoots of bamboo, the contents are gradually reduce in accordance with its growth and in the culms of the bamboo, only pentoses are predominantly present.

## SUMMARY

Aecording to the procedure of Norris and Preece, after removal of crude pectins by hot water, 0.5% ammonium oxalate treatment, the hemicellulose A of Formosan bamboo (Sinocalonus Latiforus. Munre) was extracted by 4% NaOH solution. The above residue was further extracted with 10% NaOH solution and obtained the hemicellulose B.

1. The hemicellulose A has ash contents 5.07% $[\alpha]^{25}=-73.2°$ while the hemicellulose B has ash contents 3.98% $[\alpha]^{25}=-89.2°$

2. The hemicelluloses compose of two fractions corresponding to O'Dwer's hemicellulose A and B.

3. From the hydrolyzates of hemicellulose A and B, d-xylose was isolated by crystallization. The prismic crystalls melted at 142-145°, $[\alpha]^{25}=+19.6°$ (after 70 min.).

Cadmiumbromoxylonates were prepared.

Furthermore in the hydrolyzates of the hemicellulse A and B, except d-xylose, arabinose and glucose seem to be present. This fact was further confirmed by paper patition chromatography.

However, the ketose tests (Seliwanoff, Pinoff etc.) were negative and could not find the presences of any other pentoses or hexoses in the hydrolyzates.

4. The hemicelluloses A and B may compose of either compound or mixture of 85% xylan with small amounts of araban and dextran. To clarify the structure of the hemicellulose of the Formosan bamboo, further study is necessary.

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## (中 文 摘 要)

# 關於臺灣之麻竹半纖維素之研究

楊　晃　華

據挪力斯 (Norris) 及普力斯 (Preece) 二氏實驗手續，將台灣產麻竹（採集地為台中縣竹山區鹿谷鄉秀峯村，國立台灣大學實驗林管理處清水溝營林區），以熱水 0.5% 草酸銨除去粗植物膠後，以 4% 苛性鈉溶液浸出半纖素 A，再將其殘渣用 10% 苛性鈉溶液浸出，即得到半纖維素 B。

1. 半纖維素A含有灰分5.02%，其$[\alpha]_D^{25}$為 -78.20°，半纖維素 B 之灰分含量為 3.98% 而其$[\alpha]_D^{25}$ 却為 -89.2°。

2. 此半纖維素，即相當於歐廸阿女士所講的半纖維素 A 及 B 二部分所組成。

3. 此半纖維素水解後，可得右旋木糖之結晶分離。此菱形結晶之融點為 142-145°，其$[\alpha]_D^{25}$ 為 +19.6° (70 分鐘後）。此半纖維素 A 及 B 水解時，除得右旋木糖之外，可得阿刺伯糖。此事曾以濾紙界面層析法證明之。酮糖試驗（seliwanoff, pinoff etc）結果無反應，同時於水解物中並未發見其他五碳糖或六碳糖。

4. 此半纖維素 A 及 B 由 85% 木聚醣與少量阿刺伯糖膠及菌葡萄聚醣之化合物或混合物所組成的。

若研究台灣產麻竹之半纖維素之構造，須更進一步之研究。

# 對容 (Parachor) 與
# 分子構造 (Molecular Structure)

常　淑　敏

## 前　言

前世紀中葉，化學上利用物理性質，以考證化學上所立之分子構造式，因物質性質，不但應知其中各種原子組合之數目，即所謂原子式，並且應知其中各原子互相鏈結法即所謂分子構造式。雖由分子之化合與其反應，可以知其梗概，但若能在用其物理上之性質，爲其佐證，當更覺確實。且常有分子依其化合性質，不止可立一種構造式者，更須參考其物理性質，觀察其在常態時偏重於何種。並且尙有分子上所應知而爲化學方法所不能測定者，如原子鏈互成之角，以及原子彼此之距離等等，更不得不用物理方法以測定之。 以前所常用之物理性質如液體之克分子容積 (Molar Volume) 克分子之光之折射 (Molar Refraction) 光之極面之旋轉 (Rotation of the plane of polarized light) 光之吸收 (Absorption of light) 等；近年又用對容 (Parachor) 偶極子矩 (Dipole moment) X光線及電子之繞射 (X rays and Electron Diffraction)，波力學 (Wave Mechanics) 等此篇僅用對容以測定分子構造上一切相關問題。

## 甲、對容之定義

在 1923 年 Meleod 由實驗材料而得下式

$$\frac{S^{\frac{1}{4}}}{D-d}=C=\text{常數} \qquad (A)$$

式中 S＝液體之表面張力

D＝液體之密度

d＝蒸汽密度

以上三者須在同一溫度測定，而 C 則與溫度無關爲液體物質之比常數，下表爲 Benzene ($C_6H_6$) 在各種溫度測定之 C，除表上最後一値外，其餘幾近相等，其差異之原因，由於 Benzene 之臨界溫度 (288.5°C)，測定不易精確，故可認爲係實驗之錯誤。

第一表　Benzene 之常數

| 溫　度 | 20°C | 41.5°C | 61°C | 90°C | 120°C | 150°C | 180°C | 240°C | 280°C |
|---|---|---|---|---|---|---|---|---|---|
| 常數 C | 2.638 | 2.642 | 2.647 | 2.646 | 2.643 | 2.650 | 2.641 | 2.657 | 3.372 |

於 1924 年 Sugden 以分子量 M 乘式之左側，名之爲對容，以 P 代表之，若液體分子無互相結合性質，P 亦爲常數即

$$P=\frac{MS^{\frac{1}{4}}}{D-d}=\text{常數} \qquad (B)$$

一、(A) 式內之蒸氣密度在尋常溫度比液體密度 D 所小甚多，故 D-d 可直書爲 D，換言之，$P=\frac{MS}{D}$，若再假想在表面張力等於一時之溫度則 $P=\frac{M}{D}$，因 $\frac{1}{D}$ 爲液體比容 $\frac{M}{D}$ 應爲液體之克分子容積，故 P 可認爲係液體表面張力等於一時克分子之容積。

二、在物理上凡物質在對比態 (Corresponding state) 之容積與臨界溫度之比例皆相等，Sugden 將物質之對容與臨界溫度克分子容積相比，其比例亦皆相等，故對容實當於容積。

三、在物理上，凡氣體之粘性，或用其他方法曾測得分子剖爲兩半球時剖面之面積，Sugden 以之與由粘性所得之面積相比，其比例無論任何物質皆相等，更可見對容實與容積相當。

## 乙、對容之相加性與構造性

液體之克分子容積，有相加性而兼構造性之性質，對容既與容積相當，亦必爲兼有此性質之物理性質，所謂相加性，克分子之對容，等於其中所有克原子之對容之和；所謂構造性，謂分子中原子與原子鏈結情形若不同，因鏈別力之差別，克原子之對容，必受影响，而克分子之對容，因之而有差異，故若先求得在普通鏈結上各種克原子之對容，再區別鏈結情形不同時，克分子對容應有之改變値，於是凡遇有分子構造式，須考證者。一方面由B式測定其對容；一方面再將其中每種原子之對容，以其在分子中之數目乘之，相加即得，在普通鏈結下，分子之對容，然後再將所預定之特殊鏈結情形上對容之差異，應加入或應減去之，視其與測得者相合與否，若不相符，必係所擬定之鏈結不能代表鏈結之眞相，故必另設他種之鏈結法，以求其適合，或推測其所以不符合之理由，而說明之，由是可知分子在對容上應有之構造式。

Sugden 且批評尋常用克分子容積以考證結構之法，因容積與溫度有關，故 Koph 當時規定以液體之沸點，爲測定之溫度，即同在大氣壓下。但液體之內部壓力，與其表面張力有關，而在其等壓下比較其容積，不如在同一表面張力下比較之，故表面張力不可忽視。

## 丙、克分子對容之測定法

其法與克分子容積以定克原子容積之法相同，係先由 (B) 式測有機液體之同在一組者之對容。例如碳氫化合物組，醚組，酮組等；視其分子每差一 $CH_2$ 群時對容之差異，然後集合各組之差而平均之，即爲 $CH_2$ 群之平均對容。下表所列其三組P 爲測得之克分子對容，△爲順次兩分子對容之差。

第二表　$CH_2$ 之對容

| Hydrocarbons | | | Esters | | | Ketones | | |
|---|---|---|---|---|---|---|---|---|
| 分子式 | P | △ | 分子式 | P | △ | 分子式 | P | △ |
| $C_2H_6$ | 110.5 | 40.3 | $C_2H_4O_2$ | 138.1 | 39.2 | $C_3H_6O$ | 161.5 | 36.7 |
| $C_3H_8$ | 150.8 | 39.8×3 | $C_3H_6O_2$ | 177.3 | 38.8 | $C_4H_8O$ | 198.2 | 37.5 |
| $C_6H_{14}$ | 270.1 | 39.2 | $C_4H_8O_2$ | 216.1 | 38.8×2 | $C_5H_{10}O$ | 225.7 | 39.2×2 |
| $C_7H_{16}$ | 309.3 | 35.7 | $C_6H_{12}O_2$ | 293.8 | 38.5 | $C_7H_{14}O$ | 314.1 | 41.6 |
| $C_8H_{18}$ | 345.0 | 39.6×2 | $C_7H_{14}O_2$ | 332.3 | 38.6×2 | $C_8H_{16}O$ | 355.7 | |
| $C_{10}H_{22}$ | 424.2 | | $C_9H_{18}O_2$ | 469.6 | | | | |

由上表可見兩分子差一 $CH_2$ 時，P 之差異約相等。Sugden 由多組之平均定爲 39.0 既得 $CH_2$ 之對容，進而求C 與 $H_2$ 之對容，取一飽和之碳氫化合物 $C_nH_{2n+2}$ 測其對容由其中減去 n 倍 $CH_2$ 之對容所餘必爲 2 氫原子之對容。Sugden 用 n=1 至 n=10 飽和碳氫化合物，而定氫之對容爲 17.1 以 $CH_2$ 之對容 39 減 2 氫之對容 2×17.1 得 4.8 爲碳原子之對容。

碳同氫之對容既知，再進而求有機體內他原子之對容，若欲求氧之對容，則用除碳與氫外，尙含有氧者之有機物；例如 Ether $(C_2H_5)_2O$ 以其對容減 4C 及 10H 之對容所餘爲此物氧之對容，但亦須求多物中氧之平均値，再用此法推進而得各原子之對容表。下表爲 1934 年 Pearson 及 Robinson 所校正者。

第三表　原子之對容

| 原　子 | C | H | O | N | F | Cl | Br | I | P | S |
|---|---|---|---|---|---|---|---|---|---|---|
| 對　容 | 4.8 | 17.1 | 20.0 | 12.5 | 25.0 | 54.3 | 68.0 | 90.0 | 90.0 | 48.2 |

## 丁、溶液之對容為相加性質

分子之對容既屬相加性質，溶液之對容，亦爲溶劑與溶質之對容相加。

令 $P_1=1$ 克分子溶液之對容

$P_2=1$ 克分子溶劑之對容

$P_3=1$ 克分子溶質之對容

$X$ ＝溶劑在溶液內之克分子分數

$1-X$ ＝溶質之克分子分數

故 $$P_1=XP_2+(1-X)P_3 \qquad (C)$$

求 $P_1$ 之法亦用 (B) 式

$$P_1=\frac{M_1S_1^{\frac{1}{4}}}{D_1-d_1}$$

$S_1$ ＝溶液之表面張力

$D_1$ ＝溶液密度

$d_1$ ＝蒸氣密度

$Mm$ ＝溶液之平均分子量

$M_1$ ＝溶劑之分子量

$M_2$ ＝溶質之分子量

$$Mm=XM_1+(1-X)M_2$$

由是，若溶劑之對容 $P_2$ 已知，$P_1$ 可由實驗測得，可計算其中容質之對容 $P_3$，但須容質在溶液中無分子互相結合情形者。

## 戊、對容與構造之關係

第二表所列原子基之對容，僅限於原子間之鏈結爲單鍵者，且非圜形之鏈結；如有双鍵或其中有鏈結成圜者，分子之對容不能適合於其中原子之對容之和，例如 Ethylene $H_2C=CH_2$ 其中有一双鍵若依第三表計算其對容。

$$P=2C+4H=2\times4.8+4\times17.1=78.0$$

而由 (B) 式測得之値爲 99.5 相差至 21.8 之多此決非實驗之差誤，且其他之含有一個双鍵者，亦莫不然，故必爲應有之差異，由多數求得每有一個双鍵之存在，平均必另加 23.2，對容之特點在不論原子基之種類，與雙鍵在分子中之位置，凡原子基之有双鍵者，其應加之値相等，對於三鍵及圜形之化合物亦然，例如 Benzene 爲 6 碳鏈結成圜 Puridine 爲 5 碳與 1 氮鏈結之圜

，雖圜中之組織不同，但同爲 6 原子圜，其應外加之數同爲6.1。下表所列爲對容隨鏈結情形之變更。

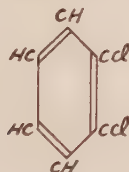
第四表　對容與構造

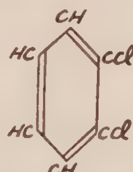
| 有 1 個 双 鍵 | 外 加 23.2 | 有1個六原子圜 | 外 加 6.1 |
|---|---|---|---|
| 有 1 個 三 鍵 | 外 加 46.6 | 有1個七原子圜 | 外 加 4.6 |
| 有1個三原子圜 | 外 加 16.7 | 有1個八原子圜 | 外 加 2.4 |
| 有1個四原子圜 | 外 加 11.6 | Naphthalene | 外 加 12.2 |
| 有1個五原子圜 | 外 加 8.6 | Ester 中之 $O_2$ | 共 計 60.0 |

上表所列 Ester 中之 $O_2$ 共計 60.0 ，係因凡 Ester 中之$O_2$ ，與他物之含有 2 氧者之對容不同， 例如第二表第六行所列之 Ester $C_6H_{12}O_2$ 之對容爲 293.8 若依第三第四二表計算之 $P=6C+12H+2O+1$ 個双鍵$=297.2$ 測得者比理論者小，凡 Ester 皆然，故變更其計算之法將 $C_6H_{12}O_2$ 中之双鍵不計，而將兩氧之値，由 $2\times 20$ 而改變爲共計 60.0，如是則 $P=6C+12H+60.0=294.0$ 與測得之値甚近。

## 乙、對容在考證分子構造上之應用

一、Benzene $C_6H_6$ 之構造　此爲化學上多年討論之問題之一。Kekule' 定爲圜形，其中有三個双鍵，若然，則下列二化合物應爲同質異形體。

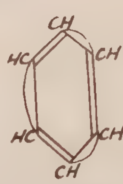



因爲兩 Cl 鏈於双鍵之兩碳，一爲鏈於單鍵之兩碳， 但實際並無兩種之分， 故 Armstron 立向心式，Thiele 立對偶式。

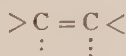



(I) 向心式




(II) 對偶式

向心式中碳之第四價俱向圜心，故免去双鍵，對偶式雖仍有双鍵但双鍵並不眞等於兩單鍵，而有未盡之餘力，Thiele 用虛線表示之，例如三、四兩式



(III)

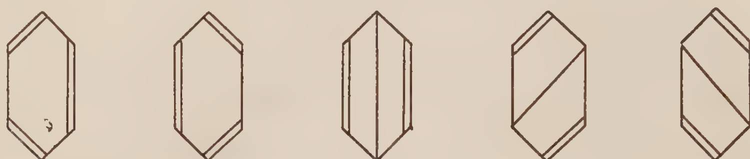


(IV)

但兩双鍵間若隔一單鍵，則中間兩隣近之碳，用其餘力，以相鏈結，而兩端之碳，則仍有餘力，如 IV 式之弧立鏈結。Thiele 比之以磁，兩端帶磁極，中間磁極互相中和，若斷開之，則爲

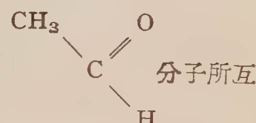
兩磁。今 Benzene 有三双鍵，中間俱隔一單鍵以成圜形，則如是以弧鏈結後必如Ⅱ式故 6C 均似爲双鍵，而彼此區別極微。

化學上對 Benzene 既有不同之構造式，故須再考證其物理性質，由光之折射率 Benzene 實應有三双鍵，再測其對容值爲 206.2， 依三双鍵計算之 P＝6C＋6H＋3 個双鍵 ＋1 個 6 原子圜依第三第四兩表應爲 207.1，可謂與測得之值相合， 近年由波力學之計算謂 Benzene 實兼有五種構造式如下

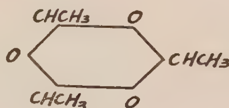


此五種構造之能力約相等，故所謂共振 (Resonance) 現象，即五態合爲一態，其能力比五態俱小，故生存更爲安定， 不過由計算共振之能力以左列之兩 Kekule' 式所供給者爲最多，故在常態時偏重於 Kekule' 式爲化學上與物理上多種性質所需要。至於向心式則爲右列三式之合併而減去左二式；對偶式則爲左二式之合態。

二、Paraldehyde $(C_2H_4O)_3$ 之構造　此物爲三個 Acetaldehyde




分子所互結而成，而其反應則無 Aldehyde 作用，故其中之 ＞C＝O 構造應不存在，化學上立下式以表示其構造。

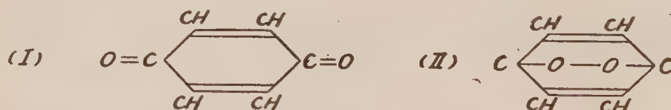



由對容之測定得 293.7 依上列構造式計算之

P＝6C＋12H＋3O＋1 個 6 原子圜＝300.1

與測得之值相近。

三、Quinone $C_6H_4O_2$ 之構造　此物曾立兩種構造式如下：




左爲 Diketone 右爲 Peroxide多數化合反應，合於左式，而物理性質如燃燒熱，與光之吸收，則合於右式，今取對容觀之，下列爲兩種有 Quinone 構造之化合物。

(a) P—Benzoquinone $C_6H_4O_2$

(b) O—Teluquinone $C_7H_6O_2$

(a) 依（Ⅰ）式 P＝6C＋4H＋2O＋4 個双鍵 ＋1 個 6 原子圜＝236.1<br>
　 依（Ⅱ）式 P＝6C＋4H＋2O＋3 個双鍵 ＋2 個 6 原子圜＝219.0

(b) 依（Ⅰ）式 P＝7C＋6H＋2O＋4 個双鍵 ＋1 個 6 原子圜＝275.1<br>
　 依（Ⅱ）式 P＝7C＋6H＋2O＋3 個双鍵 ＋2 個 6 原子圜＝258.0

由實驗得 (a) 之對容爲 236.8 (b) 爲 272.0 故 Quinone 之構造實爲（Ⅰ）式與多數化學性質正相合。

## 庚、對容在區別原子價上之應用

近日原子價理論上名稱繁多，可用對容以考證之，須先總述各種原子價種類，玆分類如下：

- 一、電原子價 (Electrovalence)
  - (一) 正價 (Positive Valence)
  - (二) 負價 (Negative Valence)
- 二、共價 (Covalence)
  - (一) 正常共價 (Normal Covalence)
  - (二) 單電子價鏈結 (Single electron linkage)
  - (三) 協合原子價 (Dative Valence)
    - 又名半極双鍵 (Semipolar double bond)
    - 又名混合双鍵 (Mixed double bond)
    - 又名配位鏈結 (Coordination link)

自 Kossel, Lewis, 及 Langm Wir 成立八電子學說 (Octet theory) 以後，化學上以原子外層之電子滿八為安定狀態，除惰性氣體外，其餘皆不滿足，原子化合之傾向由於求外層電子之滿足，故電原子價係一種原子失去其未滿足之外層之電子，以退守其內層已滿足之狀態，一種原子取得其外層所少之電子，以補足其外層滿足之狀態。失電子者，為正離子，得者為負離子。正負離子，由靜電之引力而成分子，在水內復電離為離子，失一電子者，其正電價為一，得一電子者，負電價為一，由此類推，此為電原子價。

但原子欲滿足其外層之電子，不必盡憑藉電原子價，亦可公用彼此之電子，以滿足其最外層法定之數，例如氧原子之外層，只 6 電子，而氧原子之合成分子係每一氧原子，以二電子與他原子公用，如此則取出者，只有二電子，而收回者反為四電子，故外層皆八電子。凡各以一電子公用者，相當以前之單鍵之鏈結，各以二電子公用者，相當以前所謂双鍵之鏈結法；至於三鍵之鏈結，係各以三電子為公用之電子。分子之電子結合式，係將公用之電子，置於兩原子之間，例如氫、氧、氮等分子之結合式為H:H，:Ö: :Ö:，:N:::N:，其以前之鏈結式為H−H, O＝O, N≡N, 此由以上所述之共價，兩原子所公用之電子之總數，皆為偶數。Lewis 且統計化合物分子中各原子本身外層電子相加之總數，除僅有極少數之化合物外，其餘皆為偶數。推其原因，凡電子成偶者之化合物，方能安定，故兩原子若為安定之結合，其公用之結合之電子，亦必為偶數。Lewis 進而立一原則，名為安定之電子偶。

普通共價，係每一原子皆供給公用之電子，凡已公用之電子，不得再用以結合其他之電子，但原子若尚有未置諸公用之電子偶，名為閒散之電子偶，且其閒散之電子，亦必成偶，始能安定，於是該原子亦可單獨以其閒散之電子偶作為原子間公用之電子。無須他原子之供給，而彼此亦能結合，此為共價中之協合原子價。

協合原子價有稱為半極性双鍵者，有稱為混合双鍵者，此兩名稱雖不同，而實際則無區別，普通共價係每一原子以一電子換兩電子，故可認為互相取得電子，不顯極性，故名為均態化合物 (Homopolar Compound) 至其協合原子價之公用電子，完全由一原子所供給，故有授電子者，有受電子者，其授受可認為由有閒散電子偶之原子，先以其中之一電子，授與他原子，授者為正極，受者為負極，受者以其所得之一電子，授者以其所存留之一電子，再彼此出而公用之，以結合成分子；如此，則協合原子價之化合，實為一電原子價，及一共價所合併而成。故等於双鍵之結合，Iowry 名之為混合双鍵，表示其化合種類之不單純，而 Sugden 則名之為半極性双鍵，表示其分子中有一正極之原子，有一負極之原子，但因仍有一共價在內，分子在水中不能電離為離子，而只為偶極體 (Dipole) 應有偶極子矩 (Dipole Moment) 因而其誘電係數比非偶極體者大，又分子中亦應有靜電場之存在，因而其沸點亦應比非偶極體者高，故其鏈結只為半極性而非

眞正電原子價中之極性化合物 (Polar Compound) 協合原子價之表示法，有用箭形之鏈結線，箭頭指接受電子之原子，表示結合電子之所由來，有仍用普通方法，以一線鏈結之，而於授電子之原子上畫一正號，受電子之原子上畫一負號，以表示其爲半極性。例如 Triethylamine Oxide 之化合，依上述之化合法，分爲兩階段，用電子式表示之如下：以 R 代表 $C_2H_5$ 羣。

$$R:\ddot{N}:(R)(R) + \ddot{O}: \longrightarrow R:\ddot{N}^{+}(R)(R) + \ddot{O}:^{-} \longrightarrow R:\ddot{N}(R)(R):\ddot{O}:$$

此係因氮外層有 5 電子，其中之三與R三個群作正常原子價，剩餘之兩電子，先以一電子與氧，然後又再作正常原子價之化合，所成之氧化物之鏈結式，依上述則有兩種表示法。

（I）協合原子價式 R—N(R)(R)→O （II）半極性双鍵式 R—N(R)(R)$\overset{+-}{—}$O

此爲協合原子價中之半極性双鍵與混合双鍵。

至於配位鍵之名稱，專用於 Werner 之配位化合物 (Coordination Compound) 因化學中有已化合之分子，而再互相結合者，名爲高級化合物，其化合力安在？Werner 謂原子之化合價分爲兩種：一爲主價，一爲輔價。只利用主價者爲普通化合物兩價並用者爲高級化合物。由此立配位學說 (Coordination theory)。凡高級化合物中，有一中心原子以主價兼輔價以結合他原子羣，或分子羣，其結合之數爲6或4，間或有8及10者，名爲中心原子之配位數 (Coordination Namber) 結合成一複羣以對外，有時爲陽離子，或陰離子，視其中正負電量中和之結果而定，若爲陽離子，或陰離子，彼此互可結合爲分子，亦可與普通之陰離子或陽離子結合爲化合物，此類化合物，又名爲配位化合物，依電子學說：Werner 之輔價，實相當於協合原子價在普通正常共價及電原子價外，剩餘之閒散之電子偶之作用，故分子與分子仍可結合。Werner 之配位化合物用協合原子價表示之有如下列：

$$\left[H—\underset{H}{\overset{H}{N}}\rightarrow\right]\left[\begin{matrix} O\!\!=\!\!N(\!=\!O)—O,\ H—N(H)—H,\ H \\ O—N(=O)—O—CO\leftarrow N—H \\ O\!\!=\!\!N(\!=\!O)—O,\ H—N(H)—H,\ H \end{matrix}\right]\left[:\ddot{O}—\underset{:\ddot{O}:}{\overset{:\ddot{O}:}{S}}—\ddot{S}:Ag:\ddot{S}—\underset{:\ddot{O}:}{\overset{:\ddot{O}:}{S}}—\ddot{O}:\right]^{\equiv}$$

上述化合價之理論，除電原子價外，其共價內之三種鏈結，與對容皆有關係，故對容可用以區別或考證原子價之種類。

## 辛、對容與半極性双鍵

Sugden 由對容之測定，查得凡有半極性双鍵之化合物，依第三第四兩表計算之對容，比測得者大，平均每有一個半極性双鍵，計算時，須減去 1.6 今舉數例如下：

一、Nitro 群構造例如 Nitroethane 可立四種構造式，以 R 作表 $C_2H_5$ 羣

（I） O＝N(R)＝O （II） O＝N(R)$\overset{+-}{—}$O （III） O$\overset{-+}{—}$N(R)$\overset{+-}{—}$O （IV） R—N<(O—O)

其原子結合式爲

（I） $:\ddot{O}::\overset{R}{\ddot{N}}::\ddot{O}:$ （II） $:\ddot{O}::\overset{R}{\ddot{N}}:\ddot{O}:$ （III） $:\ddot{O}:\overset{R}{\ddot{N}}:\ddot{O}:$ （IV） $R:\ddot{N}:\ddot{O}:$ (with $:\ddot{O}:$ above)

(I)式爲化學上原有之式，氮爲五價若皆認爲正常共價，則氮外共十電子，與八電子學說不合，(II)式之氮亦爲五價，因 1 個半極性双鍵，等於双鍵氮外祇有八電子。(III)式有兩個半極性双鍵，故亦爲五價，至於(IV)式則氮爲三價，今選氮化合物[illegible]之，測得 $(-NO_2)$ 群之平均值爲 73.0 計算之值如下表：

(I)式　P=1氮+2氧+2個双鍵=98 3

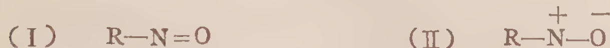
(II)式　P=1氮+2氧+2個双鍵−1個半極性双鍵=74.1

(III)式　P=1氮+2氧−2個半極性双鍵=49.3

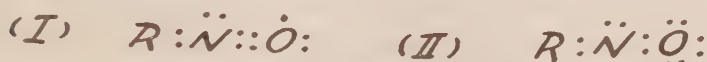
(IV)式　P=1氮+2氧+1個三原子圜=69.2

故(II)式與測得者相合 $(-NO_2)$ 羣中應中一個半極性双鍵

二、Nitroso 群之構造 (-NO) 羣可立以下兩式：一爲全係正常共價，一謂有一個半極性双鍵。



共電子結構式：

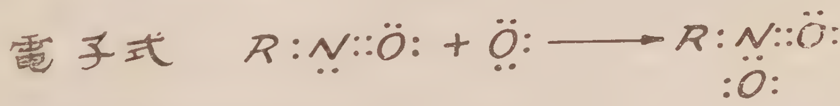


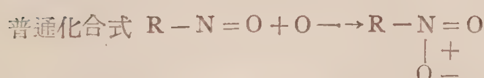
實驗測得 (-NO) 羣平均之對容爲 55.0 計算之值

(I)式　P=1氮+1氧+1個双鍵=55.7

(II)式　P=1氮+1氧−1個半極性双鍵=30.9

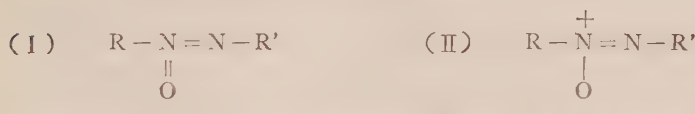
故(I)式相合即 (-NO) 羣完全爲正常共價由 (-NO) 羣加氧成 $(-NO_2)$ 羣係氮內之一個閒散電子偶用協合原子價以結合氧





與上述之 $(-NO_2)$ 羣之構造相合。

三、Azoxy 群之構造，Azoxy 羣亦可立兩式



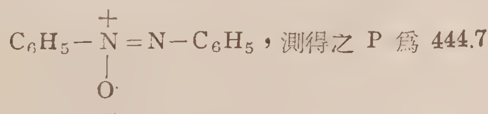
(I)爲普通双鍵式(II)式爲半極性双鍵式，測得之對容爲 64.6R 與 R' 不計，計算之値

(I)式　P=2氮+1氧+2個双鍵=91.4

(II)式　P=2氮+1氧+1個双鍵−1個半極性双鍵=66.6

故(II)式爲近於事實，可見 Azoxy 羣有一半極性双鍵，例如

令 $R=R'=C_6H_5$ 則爲 Axoxybenzene

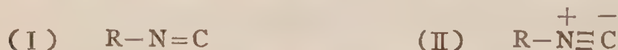


以 444.7 減去 2 個 $C_6H_5$ 羣之對容 380.0，餘爲 66.7，相當



之對容之值。

四、Triazo 羣之構造，例如 Methylazide 可立三種構造式，令 R 代表 $CH_3$



（Ⅰ）爲原來之式（Ⅱ）（Ⅲ）兩式，假定爲有半極性双鍵，N 之外層均爲八電子，測得之 P 爲 77.2 計算之 P

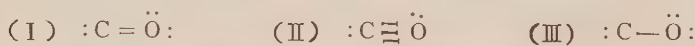
（Ⅰ）式　P＝3 氮＋1 個双鍵＋1 個三原子圜＝77.4

（Ⅱ）式　P＝3 氮＋1 個三鍵－1 個半極性双鍵＝82.5

（Ⅲ）式　P＝3 氮＋2 個双鍵－1 個半極性双鍵＝82.3

故（Ⅰ）式與實驗相合，但由電子繞射之實驗，謂 Azide 非圜形之構造，此或因（Ⅱ）（Ⅲ）之對容極近相等而與（Ⅰ）相差亦不甚遠，故（Ⅱ）（Ⅲ）式合爲該物之構造式，即謂之有共振現象。

五、Isocyanide 之構造，例如 Methyl Isocyanide $CH_3NC$，以 R 代表 $CH_3$ 可立下二式



（Ⅰ）爲原來式（Ⅱ）爲有半極性双鍵式測得（－NC）羣之平均對容爲 66 計算之值

（Ⅰ）式　P＝1 氮＋1 碳＋1 個半極性双鍵＝40.5

（Ⅱ）式　P＝1 氮＋1 碳＋1 個三鍵－1 個半極性双鍵＝62.3

可見（Ⅱ）式與測得較近其中有一個半極性双鍵

六、Carbon monoxide 之構造 CO 可立三構造式

（Ⅰ）$:C=\ddot{O}:$　　（Ⅱ）$:C\equiv\dot{O}$　　（Ⅲ）$:C-\ddot{O}:$

（Ⅰ）爲原來式（Ⅱ）爲有一双鍵，及一個半極性双鍵故碳實係四價，測得之對容爲 60.1 計算之值。

（Ⅰ）式　P＝1 碳＋1 氧＋1 個双鍵＝48.0

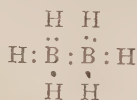
（Ⅱ）式　P＝1 碳＋1 氧＋1 個三鍵－1 個半極性双鍵＝69.6

（Ⅲ）式　P＝1 碳＋1 氧＝24.8

測得 CO 對容之值，與計算之值，雖稍偏重於Ⅱ式，但均不完全相合，故決定 CO 之構造式兼而有之，即所謂 CO 有此三式之共振結構 (Resonating Structunes)。

## 任、對容與單電子價鏈結

Lewis 雖立安定之電子偶原則，但化學上似亦有單電子之分子，例如在放電管中之 $H_2^+$，即氫分子失一電子，而成正離子，其中只有一電子，以結合兩氫之原子核，又如 Boron Hydride $B_2H_6$ 每一 Boron 原子外層有三電子，氫外層祗一電子，故該分子中各原子本身外層電子之總數爲 12，以之排列電子結合式，其中必有兩單電子鍵，係因電子不敷之故，



Sugden 謂原子價中之有單電子鍵，其對容亦反常。

總觀以上所述對容在分子構造上之應用，比以前所用之克分子容積，及光之折射範圍較廣，不但可分別双鍵三鍵及圜形，且可區別化合價之種類，所以欲知其質之確實分子構造，先測其對容以研檢之，再用其他方法加以佐證，則該質之精確分子構造　不難測出。

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# PARACHOR AND MOLECULAR STRUCTURE

by

Shu–min Chang

## SUMMARY

The application of Parachor In the analysis of molecular structure becomes more and more important than that by molar volume and by molar refraction. It is not only useful in the analysis of double bond, trible bond and Various cyclic compounds but also in that of the classifications of different Covalence. It is therefore a general review on the principle of the analysis of molecular structure by parachor and its practice was presented.

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